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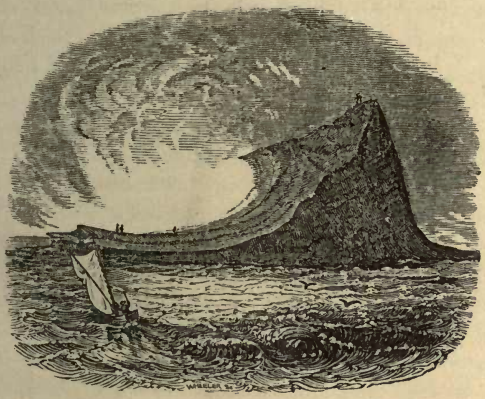

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PREFACE TO VOL. II.

THE few months that have elapsed since the preparation and publication of the 1st volume of this edition of Mantell's "Wonders of Geology" have been as productive of geological facts and theories as any such former period, if not more so. Most of the new discoveries in geology, and of the determination or correction of former hypotheses, have been described or commented upon in various communications published by the Geological Society of London; and many other points of geological interest have been treated of in papers read before the Geological Societies of Dublin, Paris, Berlin, and Vienna, or before other Scientific Societies of Europe and America.

Not to dwell upon the much-increased list of the planetoids (p. 44), to the known number of which seven have been already added,—or the additional recorded instances of aerolitic phenomena, but to refer to circumstances more closely connected with physical geology, we may draw attention to Sir C. Lyell's lucid résumé of facts relative to the secular elevation of the land,—of an abstract of a lecture on this subject not long since delivered, by the author of the "Principles," we have availed ourselves (p. 958). In another direction, our study of physical geology has of late been greatly aided by Mr. H. C. Sorby's remarkable researches in the microscopical structure of rocks, both sedimentary and hypogene, and of the component crystals of the latter (see p. 948). Mr. Prestwich's hypothetical extension of Upper Tertiary deposits over a great part of the South-east of England demands careful attention; and, though not yet clearly substantiated, and indeed still forming a geological problem

difficult of solution, has already been productive of valuable results, in setting geologists at work again over a country once thought to have been nearly exhausted of geological novelties.

But perhaps the discovery of a large granitic boulder in the heart of the Chalk of Croydon (p. 972) has been as prolific a source of geologic argument and romance as any fact lately brought forward. The outlines of the old cretaceous ocean and its archipelagos,—its shores and sea-deeps, its sea-weeds and drifted shells,—the jungles of its coasts,—and the possible icebergs of its northern limits,—offer a wide field both for the strict physicist and the imaginative geologist. With this subject is closely connected the probable existence in the early part of the Cretaceous period of a ridge of rocks, chiefly belonging to the coal-measures, ranging across the South British area, as explained and illustrated of late by Mr. Godwin-Austen (see p. 756, *note*). The presence of this old ridge in the cretaceous ocean has had two important results. In the first place it gave rise to local shingly deposits, interrupting the general succession of the sands and clays older than the Gault, and has thereby rendered it unlikely that we shall be able to obtain from beneath London such a supply of water, by means of very deep Artesian wells, as has been obtained at Grenelle from the Lower Greensand; and, secondly, it has probably borne up, as a part of its constituent mass, some coal-beds, continuous with those of Belgium on one hand, and of Somersetshire on the other; thereby *possibly* affording coal in deep borings, in this district.

In the study of fossils, so many new and interesting facts have been elucidated, that we can only refer to a few: such as Mr. Beckles's further discoveries among the Mammalia and Reptilia of the Purbeck period, and his discovery of the bones of the entire foot of the Iguanodon, which, being three-toed, may well fit some of the fossil foot-marks de-

scribed at p. 383, as having been found in deposits formed among the haunts of this great reptile;—to the descriptions, by Prof. Huxley and Mr. Kirkby, of Crustaceans of higher rank than Entomostraca in the Permian and Carboniferous deposits;—to the discovery, by the geologists of Ludlow and the neighbourhood, of many more fish-remains in the Upper Silurian than had hitherto been known;—and especially to Dr. Falconer's luminous exposition of the zoological and geological relations of the true species of Mastodon and Elephant (see p. 963).

To the results of Sir R. I. Murchison's well-sustained researches among palæozoic rocks and fossils we owe very much indeed that is new in our knowledge of the Permian and Silurian formations. Of the latter especially we have a recently corrected classification, which, elaborated by this distinguished geologist, and enriched by the labours of American, European, and British palæontologists, is, with Sir Roderick's kind permission, brought forward in this little work for the use of the student, even before its appearance in the forthcoming Second Edition of Sir R. Murchison's "Siluria." Last, not least, we must particularly notice the disentanglement of the ravelled clue to a clear knowledge of the relations of the rocks of Sutherlandshire, where Mr. Peach's late discovery of an important set of fossils in a band of altered limestone has enabled Sir R. Murchison to bring to their true bearings the observations made in this locality by himself and others, and not only to rectify errors and to disperse the obscurity which covered the geological history of the North-western Highlands of Scotland, but to place enormous masses of the stratified rocks of this region into their right places in the geological scale, and in relation with their equivalent formations in Scandinavia, Canada, Wales, and elsewhere.

T. Rupert Jones.

February, 1858.

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THE

WONDERS OF GEOLOGY.

LECTURE V.

PART I.—THE JURASSIC FORMATION: OOLITE AND LIAS.

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1. Zoology of the Chalk.—The examination of the Cretaceous and Wealden formations has afforded an instructive exposition not only of the nature of oceanic and fluviatile deposits in general, but also of the condition of animated nature at the close of the geological cycle which comprises the secondary epochs. It will therefore be expedient in this stage of our inquiry to consider the general features of the animal kingdom during the periods embraced in this review.

In the ocean-bed of the cretaceous period, we find vestiges of all the principal groups of existing marine organisms; comprising many genera of the Shark-family—viz. species of Cestracion, Lamna, Corax, &c.; with fishes related to the Chimæra, Salmon, Mackerel, Basse, &c.;—in fact, the leading types of the majority of the fishes that inhabit the present seas.* The Cephalopoda (Cuttle-fishes) and Echinodermata (Sea-urchins, Star-fishes, and Encrinites) were profusely developed; crustaceans allied to the Hermit-crab, Lobster, Water-flea, &c.; univalve and bivalve mollusca; and innumerable multitudes of Sponges, Bryozoa, and Foraminifera;—all these forms of animal existence have left enduring memorials of their presence in the seas of those remote ages. And, although we have likewise proof that numerous extinct genera, together with others now of excessive rarity, swarmed in prodigious numbers in the cretaceous ocean, and negative evidence that the Cetacea (see above, p. 325), as the Whale, Porpoise, Seal, &c., were not among its inhabitants, yet the diversified types of animated beings whose relics are entombed in these strata show that the waters of the deep possessed the same general conditions, and maintained the same relations with the atmosphere and with light, as at the present time.

The most remarkable peculiarity in the zoological features of the Chalk relates to the abundance of marine Reptiles; for, with the single exception of a lizard belonging to the family of the *Iguanidæ*, which inhabits certain parts of the sea-coasts of South America,† the Chelonians or Turtles are the only known existing marine animals of this class. But the cretaceous sea was tenanted by several Saurians of con-

* See the chronological table in M. Agassiz's Recherches sur les Poissons Fossiles, tome i.; and Morris, Catal. Brit. Foss. p. 316, &c.

† The *Amblyrhynchus cristatus* of the Galapagos Islands: see Mr. Darwin's Journal, in the Colonial Library, p. 385; and Lyell's Manual, p. 326.

siderable magnitude, — namely, the Mosasaurus (p. 319), Polyptychodon (p. 367), Ichthyosaurus, Plesiosaurus; and by others of smaller size, such as small Turtles and the eel-like Dolichosaurus.

Of the terrestrial fauna and flora, the evidence to be derived from deep-sea deposits must of course be scanty. We have, however, proof that the then dry land bore forests of pines; that ferns and plants of the cycadeous tribes formed the prevailing vegetation; and that the country was inhabited by Iguanodons, Pterodactyles, and other reptiles.

2. Zoology of the Wealden.—From data of a like nature, we learn that during the deposition of the Wealden there was an extensive region traversed by streams and rivers swarming with fishes, crustaceans, and mollusca, of extinct species, but belonging to the same principal types as those which inhabit the fresh waters of warm climates under similar conditions: and that then, as now, marsh-tortoises and crocodilian reptiles tenanted the swamps and lagoons.

Of the inhabitants of the land, we have more ample information from the relics ingulfed in the deltas and lacustrine sediments, than could be afforded by deposits accumulated in the depths of the ocean, and far from the regions whence they were derived.

Colossal herbivorous and carnivorous lizards, differing essentially in their organization from all existing reptiles, and of which no vestiges have been discovered in any strata newer than the Chalk, were the principal terrestrial vertebrata of the Wealden epoch. These, together with some small mammals, a few flying reptiles, and lizards of small size, and probably some wading birds, appear to have constituted the entire vertebrate fauna of the regions which furnished the materials of this formation. The flora consisted chiefly of ferns, coniferous trees, cycadeous plants, cypresses, and a few unknown, but apparently related forms.

In fact, the islands and continents of the late Oolitic and early Cretaceous epochs, during which time the Wealden deposits were being formed, appear to have possessed many similar zoological and botanical characters. Here then we have the first glimpse of extensive regions almost exclusively inhabited by enormous reptiles: for, though the leaves and fruits of delicate plants, the fragile bones of birds and flying reptiles, the wings of insects, and the brittle shells of molluscs with their ligaments and epidermis remaining, are abundantly found imbedded in the sediments of the rivers and seas, but few traces of mammiferous animals, and those of small size,* have been discovered in the Wealden deposits. We have now approached the *Age of Reptiles*;—that geological epoch, in which the earth swarmed with enormous oviparous quadrupeds, and the air and the waters alike teemed with reptilian forms.

3. SITE OF THE COUNTRY OF THE IGUANODON.—Before we pass to the investigation of the older secondary formations, I would briefly reconsider the question as to the geographical position of the principal tracts of country during the deposition of the Wealden and Cretaceous strata;—whether England was then dry land, and enjoyed a tropical climate; and whether turtles, crocodiles, and gigantic lizards here flourished amid groves of tree-ferns, and other productions of intertropical climes; or, on the contrary, whether the country of the Iguanodon was situated far distant from the area now covered by its spoils?

The unequivocal marks of transport which, as we have seen, the fossils of the Wealden so generally exhibit, seem to demonstrate that the reptiles and terrestrial plants could not have lived and died in the regions where their relics are imbedded: for, with the exception of the beds of river-shells and minute crustaceans, and the plants which indicate a

* The Spalacothere and Plagiaulax, and their allies, in the Purbeck series.

lacustrine condition, the organic remains frequently bear indisputable marks of having been transported from some remote country, by a river or powerful flood of fresh-water.*

The specimen of the Hylæosaurus (*ante*, p. 449) throws light on this question. Many of the vertebræ and ribs are broken and splintered, but the fragments remain near each other: and, though the bones are more or less displaced, yet they lie in situations bearing some relation to their natural positions. These facts demonstrate that the carcass of the animal must have been contused and mutilated, and that the dislocated and broken parts were held together by the muscles and integuments. In this state the headless trunk must have floated down the river, and at length have sunk into the mud of the delta, where is formed a nucleus, around which the stems and foliage of ferns and cycadeous plants accumulated, and river-shells became intermingled in the general mass. Here then we have evidence of the body of a terrestrial reptile having been transported from a considerable distance by a stream or current of fresh water; for not the slightest indication of marine detritus can be traced in the deposits in which it was imbedded. The country where this animal lived and died may therefore have been situated far from the spot where its fossil remains were entombed.

An eminent geologist † has the following remarks on this subject:—

"If it be asked where the continent was placed from the ruins of which the Wealden strata were derived, and by the drainage of which a great river was fed, we are half tempted to speculate on the former existence of the Atlantis of Plato. The story of the submergence of an ancient continent, however fabulous in history, may be true as a geological event. Its disappearance may have been gradual; and we need

* The upright trees of the Isle of Portland present an exception; but this forest may have grown on an island very remote from the mainland, inhabited by colossal reptiles.

† Lyell; Elements of Geology, Second Edition, vol. i. p. 432.

not suppose that the rate of subsidence was hastened at the period when the displacement of a great body of fresh water by the Cretaceous sea took place. Suppose the mean height of land drained by the river of the Wealden estuary to have been no more than 800 or 1000 feet; in that case, all except the tops of the mountains would be covered as soon as the fundamental Oolite and the dirt-bed were sunk down about 1000 feet below the level which they occupied when the forest of Portland was growing. Towards the close of the period of this subsidence, both the sea would encroach and the river diminish in volume more rapidly; yet in such a manner, that we may easily conceive the sediment at first washed into the advancing sea to have resembled that previously deposited by the river in the estuary. In fact, the upper beds of the Wealden, and the inferior strata of the Lower Greensand, are not only conformable,* but of similar mineral composition.

"It is also a remarkable fact, that the same *Iguanodon Mantelli* which is so conspicuous a fossil in the Wealden has been discovered near Maidstone, in the overlying Kentish-rag, or marine limestone of the Lower Greensand. Hence we may infer, that some of the Saurians which inhabited the country of the great river continued to live when part of the country had become submerged beneath the sea. Thus in our own times, we may suppose the bones of alligators to be frequently entombed in recent fresh-water strata in the delta of the Ganges; but, if part of that delta should sink down so as to be covered by the sea, marine formations might begin to accumulate in the same space where fresh-water beds had previously been formed; and yet the Ganges might still pour down its turbid waters in the same direction, and transport the carcasses* of the same species of alligator to the sea; in which case their bones might be included in marine as well as in subjacent fresh-water strata."

4. LITHOLOGICAL STRUCTURE OF THE IGUANODON COUNTRY.—The nature of the rocks and strata of which the country of the Iguanodon† was composed is also a subject of considerable interest; and from the first moment that the fluviatile origin of the Wealden suggested itself to my mind, to the time when I was compelled by ill health to quit the field of my early researches, I lost no opportunity of obtaining data by which the problem might be solved, and carefully examined the pebbles and boulders, and the fine

* The Rev. C. Fisher points out the exceptional unconformability of these deposits in Dorsetshire. Trans. Camb. Phil. Soc. vol. ix. p. 556.

† See also Petrifactions and their Teachings, chap. 3.

detritus as well as the coarser materials of which the Wealden beds are composed.

My lamented friend, the late Mr. Bakewell, kindly afforded me his valuable aid in determining the nature of the rocks whence the debris was derived; but the materials were too scanty to throw any satisfactory light upon the inquiry. In the "Fossils of Tilgate Forest," a bed of conglomerate, near Cuckfield, is described as containing pebbles of white, yellow, pink, and mottled quartz, jasper, flinty-slate, and indurated sandstone: and from this deposit I expected to obtain more satisfactory information than from the fine detritus of which the sands, sandstones, and clays consist. But with the exception of small pebbles of rock-crystal,* the substances above mentioned comprise all the transported minerals that have come under my observation. The abundance of micaceous particles in many of the sands and sandstones, and the prevalence of argillaceous and arenaceous deposits, seem to indicate a region in which were primary rocks, with sandstones and clay; for the quartz-pebbles and the micaceous sands and clays may have been derived from decomposed granitic and felspathic rocks. Extraneous fossils are rare both in the Wealden and the Chalk.† Debris of oolitic fossils, however, occur in some beds of the Lower Greensand in Surrey.

The observations of Dr. Buckland on this problem entirely accord with the result of my own investigations.

"The general absence of pebbles shows that the lands were distant

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* Small rock-crystals are often found in the sandstone near Tunbridge Wells, and are cut and set in rings and brooches by the lapidaries of that town.

† A rolled fragment of coniferous wood, which, from its state of mineralization, there is reason to conclude is from the Oolite, was found by Henry Carr, Esq., in a block of white chalk from a railway-cutting near Epsom. See Geology of the Isle of Wight, p. 140. Dr. Fitton mentions having found a rolled ammonite in the Wealden.

from whence the fine particles of sand and clay were transported. . . . . We should be inclined to look for these lands either in Devonshire or Cornwall, on the west; or in the nearest primary and transition mountains of the Continent, viz. in Normandy and Brittany, on the south-west; or in the forest of Ardennes, on the south-east. It is not probable that the materials of the Wealden formation have been derived in any great degree from the detritus of the Oolitic series, because in such case we should have found among them an admixture of pebbles of Oolite, none of which have yet been noticed."*

Of the seaward extension of the delta of the Iguanodon river, no certain indications have yet been obtained: † but it is evident that there must have been intercalations of the detritus and organic remains of the land and fresh-water with those of the sea into which the mighty stream discharged its waters; and there can be no doubt that sooner or later such fluvio-marine Wealden strata as those at Punfield and at Beauvais, when studied more extensively, will be found to throw much light on the history of the Wealden.

5. LOWER SECONDARY FORMATIONS. — In accordance with the chronological arrangement (p. 202), I proceed to the consideration of the antecedent, or lower, group of the secondary formations, namely the *Oolite*,‡ *Lias*, and *Trias*.. As a whole, the series consists of alternations of clays, marls, limestones, sands, and sandstones, abounding in marine exuviæ, and which have evidently been deposited in the basin of a sea or seas. With these strata are intercalated in some localities beds of fluvio-marine detritus, in

* Geol. Trans. 2nd series, vol. iii. p. 430.

† Mr. Godwin Austen's Map, Pl. I., vol. xii. Geol. Soc. Journ., and his observations, *op. cit.* p. 66, should be consulted on this subject.

‡ The Oolitic and Liassic rocks may be conveniently considered under the single term "Oolitic," or, still better "Jurassics." As the Jura mountain-range comprises the whole series of these rocks, the continental geologists, dividing them into groups, know them as the "White (or Upper) Jura," "Brown (or Middle) Jura," and "Black (or Lower) Jura," and collectively as the "Jurassic formation."

which vestiges of terrestrial animals and plants are imbedded.

(I shall also comprise in this Lecture a notice of the *Permian* formation, although belonging to the palæozoic system, because the mineral and some of the organic characters are conveniently described when treating of the Trias, and that the Carboniferous system may be considered in a separate discourse.)

The fossil remains of the inhabitants of the Jurassic sea comprise a prodigious number of foraminifera, zoophytes, echinodermata, mollusca, crustacea, fishes, and reptiles, nearly all of extinct forms. The fossil marine plants of this series belong to several species of algæ; and those of the land consist of such as were transported into the ocean by rivers and currents, namely, trunks and branches of coniferous trees, cycadeous plants, ferns, &c.; sometimes occurring in the state of lignite and coal. The relics of the land animals are principally of insects, with bones and teeth of numerous reptiles; and of three genera of small *terrestrial mammalia*. Evidence is thus afforded of the existence of countries clothed with a luxuriant vegetation, and inhabited by numerous reptiles and a few warm-blooded quadrupeds.

6. General view of the Oolite and Lias, or the Jurassic formation.—This formation may be described as consisting of three principal argillaceous and of an equal number of calcareous deposits; namely, Upper or Portland Oolite, and the Kimmeridge Clay; Middle or Coralline Oolite, and Oxford Clay; and Lower Oolites, and the Liassic Clays. The leading subdivisions of these strata, as they occur in England, and the names by which they are generally distinguished, are expressed in the following table. The Lias is included; for, though, in conformity with the usual geological classifications, this group of strata is placed as a separate formation in the synopsis (p. 202), we shall find it convenient, and, I believe, more in accordance with

the origin and nature of the deposits, to comprise it in a general survey of the Oolitic or Jurassic series.*

THE OOLITIC OR JURASSIC GROUP.

OOLITE.

UPPER OOLITE of the Isle of Portland, Wilts, Bucks, Berks, Oxfordshire, &c.

1. *Portland Stone*, and *Portland Sand;*—limestone, usually white, with layers of cherty flint; green and ferruginous sands: *Ammonites*, *Terebræ*, *Trigoniæ*, with other marine exuviæ; some bones of reptiles, and drifted wood.
2. *Kimmeridge Clay;*—blue clay, with septaria, bands of sandy concretion, and bituminous shale; marine reptiles, fishes, shells, corals, and other organic remains.

MIDDLE OOLITE. Wilts, Oxfordshire, Yorkshire.

1. *Calcareous Grit* and *Coral-rag;*—sandy limestone, shell-limestone, and limestone composed of corals, with shells and echini.
2. *Oxford Clay;*—blue clay, with septaria; abounding in fossils: a ferruginous sandy limestone, called *Kelloways-rock*, full of shells, is subordinate to this clay.

LOWER OOLITE. Wilts, Somerset, Gloucestershire, Oxfordshire, and Northamptonshire.

1. *Cornbrash;*—coarse shelly limestone, with clay.
2. *Forest Marble*, and *Bradford Clay;*—fissile arenaceous limestone, coarse shelly oolite, sand, grit, and clays.
3. *Great Oolite;*—Oolitic limestone and calcareous freestone; sometimes rich in shells. *Stonesfield state;*—fissile oolitic limestone, containing remains of coniferæ, cycadeæ, ferns, and algæ, marine shells and fishes; insects, reptiles, and *mammalia*.
4. *Fuller's Earth;*—marls and clays, with fuller's earth, and sandy limestones with shells.
5. *Cheltenham* or *Inferior Oolite;*—coarse limestone, with masses of trigoniæ, gryphææ, and terebratulæ; freestone and pea-grit;—ferruginous sand, with concretionary blocks of sandy limestone.

* In the Map, Pl. I. vol. i., the Oolite and Lias are denoted by the same colour and number (4).

Lower Oolite of the Yorkshire coast.

1. *Cornbrash;* a thin bed of rubbly limestone; which in many parts is a mere aggregation of shells and other fossils.
2. *Sandstones and Clays*, with land-plants; *thin coal and shale;* calcareous sandstone and shelly limestone (*Great Oolite*).
3. *Sandstone*, often carbonaceous with clays, full of leaves of terrestrial plants; *beds of coal* and *ironstone*.
4. *Limestone*, ferruginous and concretionary sands.

Lower Oolite of Brora in Scotland.

1. *Shelly limestones;*—alternations of sandstones, shales, and ironstone; with plants.
2. *Ferruginous limestone*, with carbonized wood, leaves, shells, and cypridæ.
3. *Sandstone and shale*, with *two beds of coal.*

LIAS.

Lias of Dorsetshire, Somersetshire, Gloucestershire, Northamptonshire, and Yorkshire.

1. *Upper Lias shales and limestone* (*Alum-shale* of Yorkshire), replete with remains of fishes; reptiles, especially Ichthyosauri and Plesiosauri; Crinoidea in profusion; Crustacea; belemnites, ammonites, &c.; jet at Whitby.
2. *Marlstone*—calcareous, sandy, and ferruginous strata, rich in belemnites, ammonites, pectens, and other fossil shells; wood, ferns, and cycadeous plants.
3. *Lower Lias shales and limestones*—abounding in shells, *Plagiostoma giganteum*, *Gryphæa incurva*, &c.

This list, extensive as it appears, exhibits only the principal deposits comprised in the Oolitic system. The difference observable between the lower beds of the Oolites of the South-western counties and those of Yorkshire and Scotland, in the presence of accumulations of vegetable matter in the state of coal, with the remains of terrestrial plants,—and the occurrence of the relics of Zamiæ, Insects, Reptiles, and *Mammalia*, in the Stonesfield slate, are of great interest, for

they attest the existence of land, and the action of rivers and currents. Our previous observations on the nature of oceanic deposits (vol. i. p. 57) will have prepared the intelligent reader for such intercalations of terrestrial detritus with remains of land-animals in the deposits of the ancient seas.

7. OOLITE OR ROE-STONE.—The limestones of this formation have very generally a peculiar structure, being composed of an aggregation of small rounded grains or spherules, presenting some resemblance to clusters of small eggs, or the roes of fishes; whence the name *Oolite*, or *Roe-stone*, which is now applied, not only to limestones possessing this character, but also to the entire series of deposits which intervene between the Chalk and Wealden above and the Lias below. On the Continent the group is generally termed "*Terrains Jurassiques*," from the Jura Mountains that divide France from Switzerland being largely composed of these deposits.

The oolitic structure is not however confined to this division of the secondary rocks; for it occurs in recent, in tertiary, and also in some of the most ancient sedimentary strata. It consists of an aggregation of grains or globules of calcareous matter, composed of concentric laminæ which commonly have a particle of sand, a minute shell, or a fragment of shell or other organic substance, as a nucleus. These globules owe their formation to the deposition of successive spheroidal concretions around the included body while subjected to the action of water in which a rotatory motion is induced; and the spheroids continue to increase until they become too heavy for further transport, and then subside, and are consolidated by subsequent infiltration. When the individual spheres are of a large size, the aggregated mass is called *pisolite* or peastone. The springs near Carlsbad deposit a beautiful conglomerate of this kind, some masses of which are sufficiently compact to admit of

being manufactured into boxes and other ornaments. Polished slices exhibit every variety of sections of the concentric layers of which the concretions are composed; and, as the colour varies from a pure white to a delicate brown, the surface is elegantly marked with zones of various tints.

8. GEOGRAPHICAL DISTRIBUTION OF THE OOLITE.—The strata above enumerated form a striking feature in the physical geography of England, from the southern shore of Dorsetshire to the Yorkshire coast. They constitute a table-land of considerable elevation, the greatest heights amounting to 1500 feet, which extends in a tortuous line from the Dorsetshire coast, through Somersetshire, Wiltshire, Gloucestershire, Oxfordshire, Northamptonshire, and Lincolnshire, to the eastern shores of Yorkshire. This tract generally presents a bold escarpment to the west, and slopes gradually to the east, dividing the eastern and western drainage of that part of England.*

Certain subdivisions of the Oolite predominate in particular localities; thus, the Oxford Clay prevails in the midland counties,—the grey rubbly limestone, called Cornbrash, at Malmsbury, Chippenham, &c.,—the Forest Marble, in Oxfordshire and Somersetshire,—the Great Oolite, at Bath,—the Stonesfield Slate, or rather Tilestone, near Woodstock,—and the Inferior Oolite, in the Cotteswold hills.

The Lias forms a district that lies parallel with the escarpment of the Oolite, from beneath the base of which it emerges; it traverses the country from the well-known cliffs at Lyme Regis in Dorsetshire to near Redcar, on the Yorkshire coast.†

On the Continent the Oolite appears in Normandy, and its characteristic fossils prevail in the quarries around Caen; diverging into several branches or ranges of hills, it tra-

* See Geology of Yorkshire, by Professor Phillips.

† The Western boundary of the Oolites is shown on Mr. Godwin Austen's map, Geol. Journ. vol. xii. pl. 1.

verses France, forms the chief feature of the Jura Mountains, and constitutes part of the Alps; and in the latter, strata belonging to this system appear greatly altered in their mineralogical composition from the effect of metamorphic action. The Jurassic series of Germany,* contains the lithographic stones of Pappenheim, Solenhofen, and Mannheim, some beds of which are celebrated for the beauty and variety of their fossil remains.

Jurassic rocks occur in Spain, Algeria, Sicily, Italy, Croatia, and the Carpathians; also in Russia, the Crimea, the Caucasus, Persia, and Syria. Jurassic fossils have been collected in Cutch,† in the Himalayas,‡ in Central India,§ in South Africa,‖ and to a small extent in North America.¶ The eastern coal-fields of Virginia are referred by some geologists to the Jurassic period. Oolitic fossils are also stated to have been discovered in South America.

9. RAILWAY-SECTIONS.—In a previous Lecture (vol. i. p. 373) we described the sections presented by the South-Eastern railway as affording a coup-d'œil of the geological structure of that part of England: in like manner the lines that traverse our island in other directions enable the instructed observer to obtain a general idea of the geographical distribution and position of the principal groups of the rocks and strata.

More than a quarter of a century since, the information to be derived from such a survey was admirably pointed out by Conybeare.** "If," observes that eminent geologist, "we suppose an intelligent traveller taking his departure

* For a comparative view of the Continental and the English Oolites, see Fraas, Quart. Geol. Soc. Journ. vol. vii. part 2, p. 42; and Oppel, Wirtemberg Nat. Hist. Soc. Journal, 1857.

† Geol. Trans. 2 ser. vol. v. p. 297. ‡ Geol. Soc. Journ. vol. vii. p. 306. § *Ibid.* vol. x. p. 372, and xi. p. 376.

‖ Geol. Trans. 2 ser. vol. vii. p. 193. ¶ By M. Jules Marcou.

** Geology of England and Wales, p. ii.

from the metropolis, to make from that point several successive journeys to various parts of this island, for instance, to South Wales or to North Wales, or to Cumberland or to Northumberland, he cannot fail to notice (if he pays any attention to the physical geography of the country through which he passes) that, before he arrives at the districts in which coal is found, he will first pass a tract of clay and sand; then another of chalk; that he will next observe numerous quarries of the calcareous freestone used in architecture; that he will afterwards pass a broad zone of red marly sand; and beyond this will find himself in the midst of coal-mines and iron-furnaces. This order he will find to be invariably the same, whichever of the routes above indicated he pursues; and, if he proceeds further, he will perceive that near the limits of the coal-fields he will generally observe hills of the same kind of compact limestone, affording grey and dark marbles, and abounding in mines of lead and zinc; and at a yet greater distance mountainous tracts in which roofing-slate abounds, and the mines are yet more valuable; and lastly, he will often find, surrounded by these slaty tracts, central groups of granitic rocks."

The Great Western Railway, from London to Bath, and the Birmingham line from Euston Square to Derby, respectively traverse the strata comprised in the oolitic system; for our present purpose the former will afford the most instructive illustration. From the Paddington station, which is situated on London Clay (p. 232), the line passes along tertiary strata, by Ealing, Hanwell, and Slough, and enters the Chalk near Maidenhead; beyond Wallingford it traverses the clays and limestones of the Oolite, and the cuttings in many places exhibit good sections of these deposits. Near Bath it emerges on the Lias; and, crossing a narrow belt of Triassic strata, passes on to the Carboniferous beds of the Bristol coal-measures. In this route there are several localities of considerable interest, as Farringdon, Swindon,

Chippenham, Calne, &c., to which we shall allude hereafter.*

10. SUBDIVISION OF THE OOLITE:—PORTLAND OOLITE.† —Beds of limestone having the roe-like structure above described form a principal lithological feature of the calcareous portion of the Oolite; but the uppermost deposits consist of shelly freestones, of variable structure. From the great employment of certain beds of this stone for architectural purposes, and the extensive quarries that have for centuries been worked in the Isle of Portland, this upper group is called the Portland stone. In the south of England, as we have already had occasion to mention (p. 397),‡ the Portland beds are covered by the Purbeck (Wealden) strata, including in some places layers of vegetable mould and petrified upright trunks of coniferous trees. The lower part of this group is composed of a bed of sand (*Portland sand*) from 50 to 80 feet thick, which gradually passes into the underlying clay. The fossils of the Portland beds are very numerous; large ammonites, pleurotomariæ, cerithia, trigoniæ, pectens, oysters, &c., and bones of saurians, with drifted coniferous wood, are among the prevailing organic remains.§

* See Medals of Creation, vol. ii.; Geological Excursions to Clifton, p. 864; and, for the section exposed by the Birmingham and Derby line, Excursions to Matlock, p. 867.

Mr. Hugh Miller contrasts the appearance of these railway-sections, in which the strata have a low angle of inclination (as usual with the secondary rocks of England), with those of the line from Glasgow to Edinburgh. There every few hundred yards in the line brings the traveller to a trap-rock, against which the strata are tilted at every possible angle of elevation. See "First Impressions of England and its People."

† For details of the geological phenomena exhibited by the beds below the Chalk and above the New Red Sandstone, in the south-east of England, Dr. Fitton's elaborate memoir, in the Geol. Trans. second series, vol. iv., should be consulted.

‡ See also Geological Excursions round the Isle of Wight, &c. p. 286.

§ As a British locality exhibiting the Portland strata and their cha-

11. The Kimmeridge Clay.—This argillaceous deposit consists of dark-bluish and grey clay, which in some parts passes into highly bituminous shale, known as "Kimmeridge Coal;" the name is derived from Kimmeridge in Dorsetshire, where some of the layers are sufficiently combustible to be used as fuel.* This deposit is in some places 300 feet in thickness, but thins out very considerably in the northern counties of England. It extends into France and Switzerland.

Near Hartwell, in the vale of Aylesbury, in Buckinghamshire, this clay is largely developed, and abounds in organic remains of great beauty and interest, especially Ammonites, Pleurotomariæ, Thraciæ, Pernæ, &c.; the nacreous or pearly coat of the shells of the ammonites is often as perfect and splendid with iridescent colours as in a polished shell of a recent nautilus. Many of the shells of which casts only occur in the Portland rock above are found preserved entire in the clay. A flat oyster of a deltoid form (*Ostræa deltoidea*) is very abundant, and is characteristic of the Kimmeridge clay.

Bones of Ichthyosauri, Plesiosauri, and Cetiosauri are occasionally found, also scales, teeth, and other remains of fishes, among which are mandibles of the Chimæroids.†

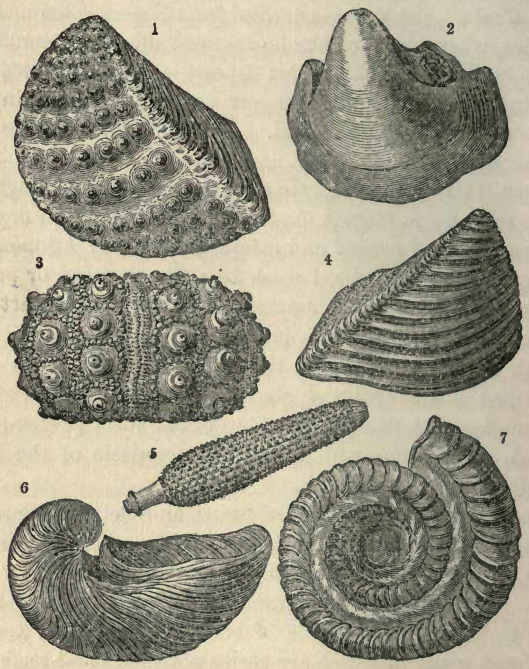
12. The Oxford Oolite, or Coral-rag.—The Kimmeridge clay rests on beds of coralline limestone, termed *Coral-rag*, many of which are really petrified coral-reefs, and

racteristic fossils, Swindon in Wiltshire is one of the most interesting. See Geological Excursions in the Medals of Creation, vol. ii. p. 862.

* See Excursions round the Isle of Wight, p. 265. This bituminous shale contains, according to the analyses of some chemists, 25 per cent. more illuminating power than Newcastle coal, when applied to manufacturing purposes. It occurs in several layers, varying from 2 to 7 feet in thickness, interstratified with dark-coloured sandy calcareous beds.

† The extensive Museum of Dr. Lee of Hartwell contains a fine collection of fossils from this neighbourhood; and strangers are allowed free access by the learned and liberal proprietor.

consist of coarse limestone, composed of stony corals, chiefly of the *Astræidæ* family, and having the interstices filled up



LIGN. 117.—SHELLS AND ECHINITE FROM THE OOLITE AND LIAS.

Fig. 1. Trigonia clavellata; from the Kimmeridge Clay.
2. ————————; a limestone-cast, from Portland.
3. Cidaris Blumenbachii; Coralline Oolite, Calne.
4. Trigonia costata; middle Oolite, Highworth, Wilts.
5. Spine of Cidaris Blumenbachii.
6. Gryphæa incurva; Lias. Cheltenham.
7. Ammonites bifrons (Walcottii, *Sow.*); Lias near Bath.

with shells, echinoderms, sand, and pebbles; the whole is more or less consolidated by calcareous, and in some in-

stances by silicious, infiltrations. So obvious is the origin of these rocks, that the most incurious observer who travels through the districts where these deposits prevail cannot fail to remark the blocks of coral which everywhere meet his view in the quarries and on the road-side. In many parts of Wiltshire, Berkshire, and Gloucestershire, the Coral-rag is extremely rich in organic remains; corals, shells, and echinites occurring in almost every mass of stone. From the pits near Farringdon * hundreds of specimens may be collected in the course of a few hours; and the quarries near Calne, in Wiltshire, abound in echinites of that beautiful species popularly called "*Fairies' night-caps*" (*Cidaris, Lign.* 117, *fig.* 3), which are often surrounded by their spines in as perfect a state as if they had just sunk down into soft sand or mud; detached spines of these animals are found (*Lign.* 117, *fig.* 5) in immense numbers.†

Many species of the bivalves called *Trigoniæ*,‡ of which only three species, inhabitants of the Australian seas, are known living, occur in these beds in great perfection and abundance; two species are here figured (*Lign.* 117); limestone-casts of these shells are very frequent in the Portland stone, and are generally accompanied with a *Cerithium*.

13. Oxford Clay.—The Coral-rag rests upon a bed of clay, in many places 300 feet thick, which is characterized

* Most of the heights around Farringdon are capped with shelly sand and sponge-gravel, referable to the Lower Greensand, overlying Coral-rag. Stanford pit, three miles south-east of Farringdon, contains:—1. Uppermost, Coral-rag, 3½ feet; 2. Limestone, with immense numbers of shells, 4½ feet; 3. Sand, 3 feet; 4. Clay. These beds abound in trigoniæ, gervilliæ, terebratulæ, ostrææ, belemnites, and ammonites; in a slab of coarse sandy limestone, four feet square, I counted above fifty gervilliæ and many trigoniæ. Between Watchfield and Shrivenham the Coral-rag is seen in openings on the road-side. See Medals of Creation, vol. ii. p. 861.

† See Medals of Creation, vol. i. p. 311, for a particular account of these fossils.

‡ Ibid. p. 412.

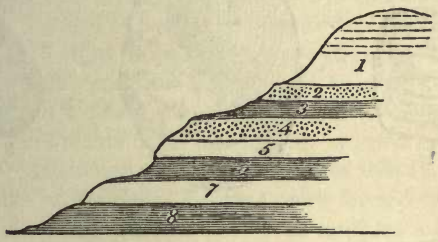
by the abundance and variety of its organic remains. Some localities in Wiltshire are celebrated for the state of perfection in which many species of extinct Cephalopoda occur. At Christian Malford, near Chippenham, the cuttings for the Great Western Railway brought to light specimens of the soft parts of the animals allied to the Sepiadæ or Cuttle-fish, whose shells are so abundant in the argillaceous deposits of the Oolite. The *Belemnoteuthis* (of Channing Pearce),* an extinct cephalopodous mollusc allied to the Belemnite,† but generically distinct, has been found with its arms entire, and the acetabula or suckers and spines attached. In the works for a branch-railway through Trowbridge, the Kelloways rock, Oxford clay, Cornbrash, and Bradford clay were largely exposed, and yielded innumerable specimens of the usual fossils, and some species of ammonites and other shells not previously observed.‡ The members of the upper part of the oolitic system occur

* See London Palæontological Journal, No. 2, Pl. XV. XVI., for beautiful figures of some remarkable specimens of these extinct Cephalopoda. Medals, vol. ii. p. 447, and p. 460. Phil. Trans. 1850, p. 393.

† For a systematic account of the Belemnites and other members of the Cephalopodous family, see Woodward's "Manual of the Mollusca."

‡ Mr. Reginald Neville Mantell made a large collection of the fossils brought to light by the cuttings and excavations in this locality. It comprised very large and fine specimens of Ammonites; Nautili; Belemnites with the phragmocone and traces of the soft parts; the cartilaginous base of the *Belemnoteuthis*; innumerable small gasteropodous shells; Ostrææ deltoideæ; Gryphææ, Terebratulæ, &c.; masses of coniferous wood and lignite; bones of Ichthyosauri, Plesiosauri, Teleosauri, &c.; and a few relics of fishes. The profusion of fossil shells dug up in the comparatively small area traversed by the railway, some of which were inhabitants of deep and others of shallow water, here and there intermingled with drift-wood, attests the effects of sub-marine currents by which the remains of molluscs of such different habitats were accumulated and spread over this area of the sea-bottom, with the spoils of the land transported from a distance by rivers. Quart. Journ. Geol. Soc. vol. vi. p. 315.

through this part of Wiltshire in their natural order of succession; as is shown in the following section (*Lign.* 118), in which the subdivisions of the Chalk and Oolite, from the Upper or flinty Chalk down to the Oxford Clay, are seen in a nearly horizontal and conformable position.



LIGN. 118.—DIAGRAM-SECTION THROUGH THE WILTSHIRE CHALK-DOWNS TO THE OXFORD CLAY.

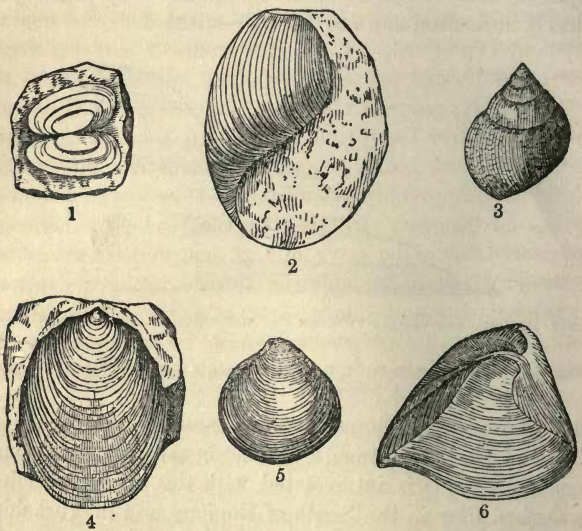
1. Upper and Lower White Chalk. 2. Upper Greensand. 3. Gault. 4. Lower Greensand 5. Portland Oolite. 6. Kimmeridge Clay. 7. Coral-rag. 8. Oxford Clay.

14. KELLOWAYS ROCK AND CORNBRASH. — A bed of gritty and sandy limestone, a few feet in thickness, and sometimes ferruginous, is intercalated with the lower portion of the Oxford Clay in the South of England and in Yorkshire, and is remarkable for the abundance of molluscan remains which it contains. It is called the Kelloways rock; hence a common species of ammonite in this deposit is named *A. Calloviensis.*

Cornbrash.—Under the Oxford Clay a hard rubbly limestone, from ten to twelve feet thick, sometimes passing into clay and sandstone, is generally met with, which, like the Kelloways rock, swarms with many species and genera of marine shells, associated with other fossils. This bed is provincially termed Cornbrash. Subjoined are figures of a few Cornbrash shells from the neighbourhood of Scarborough in Yorkshire, which were first described by Mr. Bean.*

* See *Mag. Nat. Hist.* 1839, vol. iii. p. 57.

In the South-west of England, the Cornbrash, which is persistent as a peculiar shelly deposit from the South to the North of England, is succeeded downwards by, 1st, the



LIGN. 119.—SHELLS FROM THE YORKSHIRE CORNBRASH.

Fig. 1. Sanguinolaria parvula.
2. Bulla undulata. (Occurs also in the Great Oolite of Minchinhampton.)
3. Natica punctura. (Occurs also in the Great Oolite and Inferior Oolite of Yorkshire.)
4. Anomia semistriata.
5. Cardium globosum.
6. Isocardia triangularis.

Hinton Sands and Forest Marble, together about 100 feet in thickness; 2nd, by the Bradford Clay, about 50 feet thick; 3rd, the Great or Bath Oolite, varying from 40 to 120 feet in thickness; 4th, the Fuller's Earth, a series of marly and calcareous beds, of very variable thickness, sometimes 130 feet thick; and lastly by the Inferior Oolite, a group of calcareous and sandy beds, often ferruginous, and

sometimes upwards of 200 feet thick. The Inferior Oolite extends into the Midland counties and Yorkshire, although very reduced in thickness; but the other members of the Lower Oolite beneath the Cornbrash are variously represented in the Midland and North-eastern districts, and in the North British area represented by the Oolites of Skye and Brora. Instead of marine calcareous deposits being the predominant feature, sandy and clayey deposits form the mass of the beds; and land-animals, such as insects, the Megalosaurus, and a few mammals, are found in them, whilst remains of land-plants occur occasionally in great profusion. In these circumstances we have indications that the Lower Oolitic rocks of Southern England were formed in a comparatively deep sea (though not of so uniform a depth as that of the preceding Middle and Upper Oolite periods), and that the coast-line of the then existing land lay probably at no great distance to the north-west of our Midland Oolitic area.*

The *Forest Marble* and *Bradford Clay*.—The fissile sandy oolitic beds, or tilestones, of the Forest Marble, have afforded remarkably fine specimens of ripple-markings and tracks of shell-fish and crustaceans; and have evidently originated as local shallow-water deposits, full of broken shells. The more compact shell-beds form the blue limestones, or forest marble of Wiltshire. A series of clay-beds and thin limestones succeed, but are sometimes merged into the Forest

* The student is referred to Mr. Morris's lucid comparison of the Oolitic rocks of Gloucestershire, Lincolnshire, and Yorkshire, in the Quart. Geol. Journ. vol. ix. p. 317, for detailed descriptions and much valuable information on this subject.

The admirable memoir by Mr. Lonsdale on the Geology of the country around Bath should be consulted by those desirous of more ample information on the Oolite of that part of England; Geol. Trans. 2nd ser. vol. iii. p. 242,—and Professor Phillips's Geology of Yorkshire, for a full account of the Oolite system of the eastern moorlands of that County.

Marble above, or the Fuller's Earth beds below. These clays are remarkable in the neighbourhood of Bradford, in Wilts, for the remains of a particular species of crinoid, called the *Pear-encrinite* of Bradford * (*Apiocrinus: Medals*, p. 288), which in some places occur under circumstances apparently indicating that the animals still occupy the spots where they grew. The clay is spread over the surface of a stratum of limestone, and many of the stems of these Stone-lilies are upright, with their root-like bases attached to the calcareous rock; and numerous articulations, once composing the stems, arms, and body of the animals, are scattered at random through the clay.†

15. THE COTTESWOLD HILLS.—As the elevated tract of country called the Cotteswold Hills, which extends for thirty miles through the county of Gloucester, in a N.E. and S.W. direction, having an average breadth of ten or twelve miles, exhibits the principal characters of the jurassic series of the South-west of England, the following brief description of this interesting and typical tract will be highly useful to the student.‡

The surface of this district has a general inclination to the S.E., its eastern borders having an elevation of about 400 to 500 feet above the sea; whilst the western ranges from 600 to 800 feet, and the culminating point, Cleeve Cloud, is 1134 feet high.

The branch of the Great Western Railway from Swindon to Glouces-

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* Pictorial Atlas, pl. 1. † Manual of Geology, 5th Edit. p. 307.

‡ This account of the physical geography and structure of the Cotteswolds was communicated to the author by Professor Woodward, formerly of the Agricultural College, Cirencester, now of the British Museum. The student should also avail himself of Mr. Hull's paper on the Cotteswolds, in the Geol. Soc. Journ. vol. xi. p. 477; and his "Memoir on the Geology of the country around Cheltenham," in the Memoirs of the Geological Survey, 1857, illustrative of the Sheet 44 of the Geological Survey Map.

ter passes through the centre of the district, and affords a key to its geological structure.

These hills are entirely composed of two series of oolitic limestones, separated by a bed of clay known to geologists as the "Fuller's Earth." The strata are inclined to the S.E., at the rate of about 1 in 130, or less than half a degree; yet this inclination is greater than that of the general surface, and sufficient to carry the hill-strata beneath the newer formations on the S.E.,; whilst on the north-western boundary they terminate in steep escarpments, that are broken and indented by numerous deep and picturesque valleys.

In order to obtain a general idea of the nature and succession of the strata of the whole district, we may conveniently pursue the well-known Roman road termed the "*Irmin Way*," which, coming from Newbury through the Wanborough downs, runs almost in a straight line to Cricklade, Cirencester, Birdlip, and Gloucester, and traverses in succession the whole of the oolitic strata, in the following order:—

1. Portland stone. 2. Kimmeridge clay. 3. Coral-rag. 4. Oxford clay and Kelloways rock. 5. Great Oolite: subdivided into Cornbrash, Forest marble, Bradford clay, Bath freestone, Stonesfield slate. 6. Fuller's earth. 7. Inferior Oolite. 8. Lias.

1. The *Portland stone* is extensively quarried near Swindon Old Town: 2. The *Kimmeridge clay* forms the valley in which the Swindon station and the New Town are situated: 3. The *Coral-rag* rises up from beneath the clay, and constitutes the hills about Stratton, Saint Margaret's, Pen Hill, and Blunsdon: 4. The *Oxford clay* occupies the whole of Braydon Forest, and the wide valley around Cricklade, but is covered in many places by thick beds of oolitic gravel.

5. At Driffield Cross-ways the *Cornbrash* is seen in the small quarries from which the road-stone is procured; and in descending the hill towards Cirencester we pass to the *Forest marble*, a thin-bedded stone, well shown in the quarries at Preston, from which much of the roofing-stone and planking, so extensively used in the neighbourhood, is obtained. A bed of clay is usually found separating the Forest marble from the Bath freestone, and is therefore the equivalent of the *Bradford clay* Beyond Stratton the road lies over the Bath freestone (or "*Hampton stone*") as far as Highgate, where several deep valleys expose the *Stonesfield slate*, *Fuller's earth*, and *Inferior Oolite*.

The quarries near Birdlip also exhibit the Inferior Oolite, and the remainder of the road to Gloucester rests upon the *Lias*.

If an Artesian well were sunk at Swindon New Town, it would probably pass through the above-mentioned strata, from the Kimmeridge

clay to the Lias, in the same order in which they are passed over by the Irmin Way, reaching the surface of the Lias at a depth of about 1000 feet.

16. THE GREAT OOLITE AND STONESFIELD SLATE.—The Great Oolite of the Western Counties is a calcareous series, in which the well-known Bath Oolite is imbedded. As we trace this series towards the north-east, it becomes much modified, and the lower beds appear to pass into the celebrated Stonesfield Slate * (or tile-stone).

Stonesfield, a small village near Woodstock, about twelve miles north-west of Oxford, has long been celebrated for the fossils imbedded in its thin-bedded limestone; † bones and teeth of large reptiles and of fishes, and other remains from this locality, were described and figured by Lhwyd, more than a century ago.‡

Dr. Buckland's memoir on the great fossil reptile of Stonesfield, the Megalosaurus,§ where he at the same time mentioned the discovery of mammalian jaws in the same deposits, drew special attention to this interesting locality.

The Stonesfield strata have been ascertained, by Mr. Lonsdale, to belong to the lower division of the Great Oolite; from Dr. Fitton's description ‖ of the circumstances under which they occur, we learn that in crossing the country from Oxford to Stonesfield, the Oxford clay with its characteristic fossils is first observed; this is succeeded by the Cornbrash—the uppermost stratum of the Great Oolite group, which is seen beneath the clay in several quarries on the sides of the road to Woodstock and Blenheim. . . . . The village of Stonesfield is situated on the brow of a valley, both sides of which are deeply excavated by the shafts

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* Phillips's Manual of Geology, p. 303.

† Commonly called *Stonesfield slate.* As the term "slate" is technically applied to the old metamorphic *clay-slates* only, it is misapplied to the laminated rock of Stonesfield, which is fissile by its stratification, not by "cleavage."

‡ Lithophylacii Britannici Ichnographia.

§ Geological Transactions, second series, vol. i. p. 390.

‖ Zoological Journal, vol. iii. p. 416.

and galleries that have been constructed for the extraction of the "slate." The beds that supply the stone are at a depth of about fifty feet below the summit, and are worked by shafts. The upper twenty-five feet consist of clays alternating with calcareous stone; the lower of fine-grained oolitic limestone, with numerous casts of shells. From the bottom of the shaft, drifts or horizontal excavations are made around, extending as far as safety will permit; the beds above being supported by piles of the less valuable materials. The strata thus worked do not exceed six feet in thickness; they consist of sandy beds imbedding large calcareous concretions, which, by exposure to the frost, admit of separation into thin flakes.

Fissile calcareous concretions, similar to those of Stonesfield, occur also at Wittering and Collyweston, associated with sandy beds and oolite limestones, and contain ferns and other terrestrial plants, together with marine shells.

17. ORGANIC REMAINS OF THE STONESFIELD SLATE.—The majority of the fossils of Stonesfield, although of so highly interesting a character, have hitherto been very imperfectly investigated. The vegetable remains consist of fucoidal plants, and of palms, arborescent ferns, and plants allied to the Zamia and Cycas, with seed-vessels, leaves, and stems of coniferæ, and traces of reed-like plants. The shells are jurassic in their character; and one small bivalve (*Trigonia impressa*) is extremely abundant. The bones and teeth of the gigantic terrestrial reptile related to the Monitor, the *Megalosaurus*, mentioned above as occurring in the Wealden (vol. i. p. 435), bones of Pterodactyles or flying lizards, bones and plates of Turtles, and other osseous remains, apparently of saurians, present a striking general correspondence with the fossils of the Wealden. The *elytra* or wing-cases of beetles, and other relics of insects, are of frequent occurrence. The teeth, scales, fin-bones, and rays of fishes belong for the most part to the same genera and species as those contained in other jurassic strata; teeth of *Lepidotus* and *Hybodus* are frequently met with;* but

* See Buckland's Bridgwater Treatise for figures of several fossils from Stonesfield.

by far the most interesting fossils are the mammalian remains.

18. FOSSIL MAMMALIA OF STONESFIELD.*—The laminated oolitic limestones of Stonesfield have yielded some of the most precious relics of the past ages of our globe—most

LIGN. 120.—THE RIGHT SIDE OF THE LOWER JAW OF A MARSUPIAL MAMMALIAN; STONESFIELD.
(From Zoolog. Journ. vol. iii. pl. xi.)

Fig. 1. Natural size. Fig. 2. Enlarged view of a single tooth.

(*Phascolotherium Bucklandi*).†

of the known vestiges of mammalian animals ‡ in the secondary formations, in other words, in deposits of an age

* See Prof. Owen's Memoir in the Geol. Trans. 2 ser. vol. ii. p. 147; Medals of Creation, vol. ii. p. 805; Petrifactions, p. 401.

† The original is in the British Museum; it is in an admirable state of preservation; and the piece of rock in which it is imbedded has numerous casts of the *Trigonia impressa*, which occur in such profusion in the Stonesfield tilestone.

‡ Emmons's *Dromatherium*, from the Chatham Coal-field of North Carolina, and Plieninger's *Microlestes*, from the Wirtemberg Bone-bed, are Mammalia of still more ancient date.

long antecedent to the mammaliferous eocene epoch :—a fact of the highest interest to the geologist, since it carries back the existence of the higher vertebrated animals to a period of unfathomable antiquity.

The mammalian remains hitherto discovered comprise, firstly, a portion of lower jaw, with teeth, of a small pachydermatous animal (the *Stereognathus*),* nearly related to some of the Eocene mammals, such as the *Hyracotherium* and *Pliolophus ;* † and, secondly, at least seven specimens of portions of lower jaws, with teeth, belonging to very small animals, and referable to two genera. One of these is allied to the Wombat (*Phascolomys*), a marsupial animal of New South Wales; proving that the remarkable character of the mammalian fauna of Australia also prevailed in a very remote period, and that it is not, as some have inferred, a new order of things. The other was a small insectivorous mammal (*Amphitherium*), having thirty-two teeth in the lower jaw; its marsupial affinities are doubtful.‡

19. Comparison of the Stonesfield and Wealden Fossils.—We have seen that the zoological characters of the Oolite and Lias are decidedly marine, with intercalations of materials brought down by rivers into the sea, and transported by currents to a more or less distant part of the oceanic basin. Unlike the organic remains of the Wealden, the terrestrial and fresh-water productions are mingled with marine plants, shells, and fishes. Thus, while the Chalk consists of the bed of a deep sea with scarcely any intermixture either of land or fresh-water debris, and the Wealden of a delta in which but few marine exuviæ are imbedded, the Lower Oolitic series presents an intermediate character, of which the Stonesfield strata afford a highly interesting ex-

* Quart. Journ. Geol. Soc. vol. xiii. p. 1.

† Described by Prof. Owen in Geol. Proceed. for May 20, 1857.

‡ In Prof. Owen's "British Fossil Mammals," are exquisite figures and an elaborate philosophical notice of the mammalian remains discovered in the "Stonesfield slate." See also Lyell's Manual, p. 312.

ample. The reader cannot fail to mark the general correspondence that exists between the organic remains imbedded in these fluvio-marine deposits of the Oolite and those of the Wealden: * the following tabular view will render this analogy more obvious—

Wealden and Purbeck Strata.	*Stonesfield and Collyweston Slates.*
Drifted coniferous wood and lignite.	Drifted coniferous wood.
Equiseta.	Fucoidal plants.
Ferns: Sphenopteris, Lonchopteris, &c.	Ferns: Sphenopteris, Tæniopteris, &c.
Cycadaceæ.	Cycadaceæ.
Carpolithes, and undetermined seed-vessels.	Carpolithes, and undetermined seed-vessels.
Fresh-water shells: Paludina, Cyclas, Unio, &c.	Marine shells — Pteroceras, Trigonia, &c.
Freshwater Crustaceans: Cypridæ.	Marine Crustaceans: Astacidæ, &c.
Insects: numerous genera.	Insects: several genera.
Fishes of the genera Hybodus, Lepidotus, &c.	Fishes of the genera Hybodus, Lepidotus, Strophodus, &c.
Marine and Fresh-water Chelonians.	Marine Chelonians.
Reptiles: *marine* — Plesiosaurus and Cetiosaurus.	Plesiosaurus and Cetiosaurus.
——: *terrestrial* — Megalosaurus, Hylæosaurus, Iguanodon, &c.	Megalosaurus.
Crocodilian—Goniophilis, Pœcilopleuron, &c.	Teleosaurus.
Pterodactyles.	Pterodactyles.
Birds?	Birds?
MAMMALIA: several genera (Purbeck).	MAMMALIA: three genera.

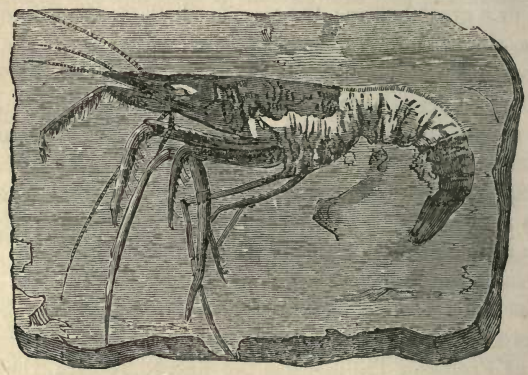
From this table we perceive at a glance, that the fauna and flora of the dry land during the deposition of the Stonesfield oolite and the Wealden-strata were essentially the same; while the difference in the mollusca points out the respective conditions under which the deposits took

* See also Fossils of the South Downs, &c. 1822, p. 37 and 59.

place: and the same may be said more or less exactly on comparison of the estuarine jurassic beds of Skye and Brora, and of Yorkshire, with the Wealden series. The fresh-water shells of the Wealden indicate the bed either of a delta or a great lagoon; the marine shells of the Stonesfield strata, the basin of a deep sea. Nor can we resist the conviction that not only did the same terrestrial area, however modified it must have been during the long succession of ages, supply the debris of an almost unchanged system of animal and vegetable life to the jurassic seas at first, and subsequently to the cretaceous ocean, but that also the fauna and flora of this ancient land of the secondary epoch had many important features which now characterize Australasia. The Stonesfield marsupials and the Purbeck *Plagiaulax* are allied to genera now restricted to New South Wales and Van Diemen's Land; and it is a most interesting fact, as Professor Phillips was the first to remark, that the organic remains with which these relics are associated also correspond with the existing forms of the Australian continent and neighbouring seas; for it is in those distant latitudes that the waters are inhabited by Cestracions, Trigoniæ, and Terebratulæ; and that the dry land is clothed with Araucariæ, Tree-ferns, and Cycadeous plants.

20. Lithographic stone of Germany.—The quarries in Germany which yield the fine-grained fissile calcareous stone so much employed in lithography, and belonging to the upper portion of the jurassic series, afford also a rich assemblage of organic remains, of the highest interest. This deposit is found in that prolongation of the chain of the Jura which, after the fall of the Rhine at Schaffhausen, passes into Germany along the borders of the Maine and near to Cobourg. The quarries are situated on the sides of the valley of the Altmuhl, a tributary of the Danube, that extends by Pappenheim and Aichsted. This valley presents a precipitous escarpment, which is composed of, 1. (the upper-

most part), fissile calcareous rock, containing in abundance fishes, crustaceans, echinoderms, and reptiles, with a few small ammonites and bivalve shells;—2. a magnesian limestone;—



LIGN. 121.—FOSSIL PRAWN, FROM PAPPENHEIM.

(*Æger spinipes.*)

3. limestone of a greyish-white colour, abounding in ammonites; and 4. brown or grey sandstone, of a fine grain, constituting the base of the hills of the district.* The most celebrated quarry of the laminated limestone is that of Solenhofen, near Pappenheim. The cream-coloured limestone of this quarry has long been known to contain organic remains of great beauty and interest. Crustaceans allied to the Lobster, Shrimp, &c., are often met with, and many specimens are figured by authors. Knorr's "*Monumens des Catastrophes que le Globe terrestre a essuie*" contains numerous coloured representations of these fossils. The Prawn-like crustacean here figured (*Lign.* 121) shows the extraordinary state of preservation of these remains. Cro-

* For the relative age of these Jurassic rocks of Bavaria, see Fraas's Memoir, Geol. Soc. Journ. vol. vii. part 2, p. 74.

codilian, Pterodactylian, Chelonian, and other reptiles, upwards of sixty species of fish, forty-six of crustaceans, and twenty-six of insects, have been collected in the Solenhofen beds by Count Münster.* There are but few shells and plants, and these are marine.

Sir H. De la Beche has remarked, that the fact of the greatest number of fossil Insects yet noticed in the Oolite having been found where the remains of the Pterodactyles principally occur seems to establish a connexion between these creatures, not merely accidental; and that it is probable the whole of the deposits of this local group of the Jura-limestone (and those also of Stonesfield) may have been effected on a coast where the water was not deep, and on the shores of which the flying reptiles chased their insect-prey.† The association of insectivorous mammals and reptiles with innumerable relics of insects in the Purbeck beds of Dorset is of equal interest.‡

21. Coal-bearing Strata of the Oolite.—We noticed the occurrence in the tertiary system of Provence of beds of coal with limestone containing fresh-water shells and crustaceans (vol. i. p. 264); and in the lacustrine deposits of the Rhine, accumulations of brown-coal and lignite (p. 283). In the Wealden of the South-east of England, lignite and thin seams of coal are associated with shale and laminated sandstones, so much resembling the ancient carboniferous beds as to have led to an expensive and abortive search for coal; while in the north of Germany the Wealden contains a rich coal-field of considerable extent. The fluvio-marine strata of Stonesfield, though teeming with vestiges

* See Münster's Beiträge zur Geognosie und Petrefactenkunde, for descriptions and figures of numerous fossils from the Solenhofen deposits.

† A beautiful fossil Dragon-fly from Solenhofen is figured in Medals of Creation, vol. ii. p. 551.

‡ See Prof. Owen's remarks, Journ. Geol. Soc. vol. x. p. 432.

of land-plants, enclose no considerable masses of vegetable matter; but in the extension of these lower beds of the Oolite northward, indications of lignite and carbonized plants become more abundant; and along some parts of the Yorkshire coast seams of coal and numerous fossil vegetables occur; proving that the currents of fresh water which flowed into that part of the jurassic sea were occasionally loaded with trees and terrestrial plants, transported from the lands inhabited by the Megalosaur, Pterodactyles, and small Mammalians, the remains of which are found at Stonesfield. On the eastern and the western shores of Scotland, strata of a similar character are exposed.

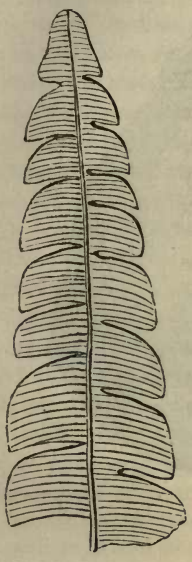
Professor Phillips has described the coal-bearing beds of the Yorkshire Oolite,* and Sir R. Murchison those of Sutherlandshire;† the tabular arrangement at p. 491 shows the succession of the deposits in these two localities.

In Yorkshire the lower Oolite is represented by, 1. a thin Cornbrash limestone; 2. a thick mass of sandstones and shales abounding in coaly matter; and 3. ferruginous sandy beds, overlying the Lias. The carbonaceous matter takes the form of seams of coal, which, though thin, are, from local circumstances, of considerable value. These strata assume the appearance of a true coal-field, with subordinate beds of coarse shelly limestone. Indeed, Prof. Phillips has remarked that in the Lower Oolitic series of Yorkshire there are five plant-bearing bands of sandstone and shales (occasionally yielding coal in three zones), four calcareous bands, and several layers of ironstone. Here, observes Professor Phillips, we have truly a coal-field of the Oolitic era, produced by the intercalation of vast quantities of sedimentary detritus loaded with vegetable matter, brought down by floods

* Encyclopædia Metropolitana, art. *Geology;* Manual of Geology; and the Geology of Yorkshire, by the same eminent philosopher. See also Geol. Proceed. for June, 1857.

† Geol. Transact. 2nd series, vol. ii. p. 293 and 353.

from the land, between the more exclusively marine strata of the ordinary Oolitic type. The fossil plants which accompany the coaly sandstones occur also in the calcareous beds, both on the Yorkshire coast and at Brandsby. No marine exuviæ have yet been found in the coal-grits or shales. Along the coast under Gristhorp cliffs, a seam of shale, but a few inches in thickness, may be traced for miles; and, from its abounding in leaves of ferns and equisetaceous and cycadaceous plants, it is chiselled out by collectors to obtain specimens; for the beauty and variety of these fossils render them objects of great interest. Detached leaves (*Lign.* 122) in a carbonized state are very abundant, and their venation is generally well preserved. Professor Phillips has figured several kinds in his "Geology of Yorkshire:" and numerous species are described in Lindley and Hutton's "British Fossil Flora." * The fruits of Zamia-like plants also occur, and many splendid examples are preserved in the British Museum † and other collections. This specimen (*Lign.* 123) shows the usual appearance of these fossil fruits; it is imbedded in dark ironstone-shale, and the leaves and their imprints are covered with a white hydrate of alumina. Some of the fossils that have been described as flowers are conjectured to be bodies of this kind, broken transversely, in which state the



LIGN. 122.—PART OF A LEAF OF PTEROPHYLLUM COMPTUM; from near Scarborough.

* See also Quart. Geol. Journ. vol. vii. p. 179; and Medals of Creation, vol. i. p. 152.

† Petrifactions, p. 55.

scales may be mistaken for petals, and the fractured axis for the stamen and pistillum.

LIGN. 123.—FRUIT OF A CYCADACEOUS PLANT FROM SCARBOROUGH.

The seeds are concealed by the leaflets.

(Zamites lanceolatus.)

22. COLLYWESTON TILESTONES.—Near Stamford, in Lincolnshire, the lowermost visible strata are Lias-clays, upon which are spread the ferruginous beds of the Inferior Oolite; and above are beds of laminated calcareous stone, locally termed the "Collyweston slates," from being quarried in that neighbourhood.* These deposits, therefore, appear to

* See Quart. Journ. Geol. Soc. vol. ix. p. 335.

occupy the same geological position as the Stonesfield tilestone of Oxfordshire and of the Cotteswold hills, and contain similar marine shells. They are associated with marly limestone. The fossils are shells of the genera *Pteroceras*, *Nerinæa*, *Lucina*, *Modiola*, *Trigonia*, &c., with numerous fragments of the leaves of ferns (especially of *Pecopteris polypodioides*), and of cycadaceous plants. These beds have been regarded by Captain Ibbetson and Mr. Morris as the equivalents of the carbonaceous shales of Scarborough and Gristhorp Bay; in fact, as the seaward extension of those fluvio-marine strata. Those of Stonesfield appear to have been synchronous, but deposited still farther from land.

23. Coal-bearing Oolite of Brora.—Carbonaceous fluvio-marine deposits of a similar character to, and of the same Lower Oolite age as, those above described occur in the north of Scotland.* At Brora, on the south-east coast of Sutherlandshire, intercalated between the Middle or Oxfordian Oolites and the Lias, there is a series of deposits consisting of, 1st, shelly limestones, representing the Cornbrash and Forest-marble; 2. sandstones, shale, and ironstone, with remains of land-plants; 3. shelly limestone with fossil wood; 4. sandstone and shale with plant-remains, and containing towards the top two beds of coal. In the neighbourhood of Elgin also, and on the north-east coast of the Isle of Skye, shales and sandstones with impressions and remains of similar plants are met with, superimposed on the Lias.†

The fossil plants are for the most part of the same type as those of Yorkshire, and are associated with fresh-water or brackish water shells of the genera *Cyclas* or *Cyrena*, *Unio*, and *Paludina*. *Tellina* and *Perna* have also been found; and

* For a general view of the geological phenomena of Scotland, the reader is referred to the instructive little volume by Prof. James Nicol, entitled, A Guide to the Geology of Scotland, 1844.

† Sir R. Murchison, Geol. Trans. 2 ser. vol. ii. p. 293; Mr. Robertson, Geol. Proceed. vol. iv. p. 173, and Geol. Journ. vol. iii. p. 113; and Prof. E. Forbes, Geol. Journ. vii. p. 107.

Cypridæ (p. 419) occur in profusion. Scales and teeth of numerous small ganoid fishes, of genera common in the Oolite (*Hybodus*, *Lepidotus*, and *Acrodus*), abound in some of the layers of clay: fragments of plates and bones of Chelonians are among the few reptilian relics hitherto observed.

These coal-bearing deposits have evidently had the same origin as those of north-eastern Yorkshire, where Uniones and Cypridæ are associated with Ferns, Zamiæ, Thuyites, and other terrestrial plants. Taken as a whole, the fluvio-marine intercalations of the Oolite must be regarded as local accumulations of the spoils of the land, transported into the sea by the agency of rivers; the presence of coal depending on the streams being largely charged with vegetable remains; or perhaps, in some cases, to the subsidence and covering up of swamps and lagoons rich with vegetable growths. They belong to a period long antecedent to the deposition of the Wealden, which was subsequent to the formation of the upper Oolites.

24. Jurassic Coal-field of Eastern Virginia.—One of the most remarkable features in the geology of the United States of North America, as contrasted with that of Europe, consists in the absence of deposits yielding jurassic fossils such as, throughout large tracts in England and Europe, represent the vast interval of time that must have elapsed between the close of the Triassic and the commencement of the Cretaceous epoch. Some time since, it was suggested by Professor W. B. Rogers, that an extensive coal-field in Eastern Virginia* belonged to the Jurassic period; and Sir C. Lyell coincides in this opinion. This coal-field is about twenty miles from north to south, and from four to twelve miles in breadth from east to west. It is situated in a

* There are two coal-fields in the State of Virginia: the remarks in the text exclusively refer to the Eastern coal-field,—that near Richmond; the coal-measures in Western Virginia belong to the ancient Carboniferous system.

granitic region, and the lowermost bed of coal rests upon granite. Quartzose grits, sandstones, and shales are intercalated with the coal, as in the carboniferous system of Europe. Beds of rich bituminous coal, one being in some places from thirty to forty feet thick, occur in the lower division.*

The fossil plants resemble those of the Oolite of Yorkshire (*Pecopteris Whitbiensis*, *Equisetum columnare*, some species of *Zamites*, *Tæniopteris*, *Neuropteris*, &c.), differing specifically, and most of them generically, from those of the older coal-formations. From the upright position of many of the Equiseta, Sir C. Lyell infers that the vegetables which produced the coal grew on the spot where they are now found, and that the strata were formed during alternate subsidences and elevations of this part of Virginia. They contain fossil fishes (*Tetragonolepis* and *Catopterus*†) related to European Liassic species; and numerous *Cypridæ* and *Estheriæ*, the latter of which, under the name of *Posidonomyæ*, are characteristic of some strata of the European Trias. Prof. Rogers finds reasons to regard this coal-field of Eastern Virginia as belonging to the same series of deposits as the red sandstones and coaly shales of Carolina to the South, and of Maryland, New Jersey, and Connecticut, to the North. These beds are characterized by the local occurrence of *Estheriæ* and *Cypridæ*, reptilian bones, and plant-remains; and in Connecticut, by numerous impressions of supposed birds' tracks. They have been variously referred to the Trias and the Permian series; but probably more or less fully represent in time, as extensive land and

* Plant-beds and coal of similar characters as the above have been found near the Rocky Mountains, at Raton Mountain and Muddy River.

† Sir P. Egerton's genus *Dictyopyge* consists of some of Mr. W. C. Redfield's *Catopteri*. See Silliman's Journal, 1856, vol. xxii. p. 357, and Geol. Soc. Journal, vol. iii. p. 275.

fresh-water formations, the Upper Trias and Lower Jurassic periods.*

In India and South Africa, and probably in Australia, similarly characterized deposits, possessing both Triassic and Jurassic elements, are recognized.†

In the Chatham coal-field (North Carolina), of this age, Dr. Emmons ‡ has discovered some lower jaws of a small species of mammal, which he has named *Dromatherium sylvestre*. They much resemble some of the little marsupial jaws from Stonesfield and Purbeck. Dr. Emmons has also figured and described § a fossil sacrum of a bird from the same series of deposits,—referred by him to the Permian age.

25. THE LIAS.—The lowermost group of the Oolitic or Jurassic system, termed the LIAS, consists of stratified blue and grey marls, clays, and limestones, amounting in total thickness to from five hundred to one thousand feet, and abounding in many peculiar fossils. The principal lithological features are the uniform aspect and distinctly stratified character of the limestones and intervening argillaceous layers; the most constant subdivisions are those mentioned in the table, ‖ p. 490.

* The Wealden may in like manner be said to be the equivalent of the Upper Jurassic and Lower Cretaceous series.

† See Mr. T. R. Jones's remarks on this subject in the Geol. Soc. Journ., vol. xii. p. 376.

‡ American Geology, part vi. p. 35, 1857.

§ Ibid. p. 148.

‖ In 1856 Dr. T. Wright, of Cheltenham, published in the Quarterly Journal of the Geological Society a paper, to show that the sands usually referred to the Inferior Oolite in the West of England contain fossils of the Liassic type, and should be classified as with Lias, and not with the Lower Oolite. Although Mr. Hull, of the Geological Survey, has accepted Dr. Wright's views, and carried them out in his description of the geology of the country around Cheltenham (Memoirs Geol. Survey, 1856), yet there are too many dissentients to these views amongst experienced geologists, and too many openings for criticism in

It may be stated in general terms, that the Lias of England extends along the western escarpment of the Oolite, from Yorkshire to the Dorsetshire coast, forming a district which presents an exceedingly variable surface, occasioned by the disruption and subsequent denudations which the strata have undergone.

The Lias,* from its northernmost limits on the Yorkshire coast, where it underlies the strata of the Eastern Moorlands,† passes to the south of Whitby and to the east of York, and crosses the Humber near the junction of the Trent and Ouse; stretching onward beneath the low Oolitic range of Lincolnshire, it extends to the Wold hills, on the borders of Nottingham and Lincoln, to Barrow-upon-Soar; whence it continues, accompanying the escarpment of the Inferior and Great Oolite, through Nottingham, Warwick, and Gloucester. Its whole course, to within a few miles south of Gloucester, is remarkably regular, presenting an average breadth of about six miles, bounded on the south-west by the Oolite, and on the north-west by the Red Marl, which will hereafter be described. Beyond Gloucester, its range becomes intricate: its eastern limit accompanies the Oolite through Somersetshire to Lyme Regis; but the western is very irregular, feathering in and out among the coal-fields which occur towards the estuary of the Severn and the upper part of the Bristol Channel, Gloucestershire, Somersetshire, Monmouthshire, and Glamorganshire, and attended with numerous outlying or detached masses. To render the course and position of the Lias in this part of England intelligible, it is necessary to state, that this dis-

Dr. Wright's arguments, to allow of our altering the present classification of these beds, which, though possibly passage-beds, and partaking of the characters of the two series, have too much in common with the Oolite to be separated from it.

* Outlines of the Geology of England and Wales, p. 261.

† In the Lias of the Eske Valley there are two great beds of iron-stone, which are extensively worked.

trict is occupied by three great basins of the coal-formation, encircled by the underlying Mountain-limestone and De-

LIGN. 124.—SECTION FROM SOUTH OF MALMESBURY THROUGH THE MENDIP HILLS.

1. Mountain-limestone, overlying Devonian rocks. 2. Millstone-grit, underlying the coal-beds. 3. Triassic and Permian strata. 4. Lias. 5. Inferior Oolite. 6. Great Oolite. 7. Oxford clay.

*(From the Geology of England and Wales.)**

vonian sandstones; one of these basins is shown in the annexed section.

The edges of these basins consist of strata thrown up at a high angle, and often nearly vertical, forming bold and precipitous ranges of hills; in the valleys, horizontal layers of Lias, with subjacent beds of red-marl (*Lign.* 124), are seen lying unconformably upon the highly inclined coal-measures. I shall recur to this subject hereafter, and now only observe, that the Lias appears beneath the Oolite through the south-east of Somersetshire, and passes into Dorsetshire, where the overlying Greensand conceals it beneath the high range of the Black Down Hills.

At Lyme Regis it forms a range of cliffs, about four miles in length, and may be traced until it gradually sinks beneath the Inferior Oolite of Bridport. The skeletons of large marine reptiles (*Ichthyosauri* and *Plesiosauri*), for which the Lias is celebrated, have principally been found in the cliffs at Lyme, Watchett, Westbury, and Whitby, where the natural sections, formed by the action of the waves, well

* The inclination of the strata is very much exaggerated in this diagram, in consequence of the difference in the horizontal and vertical scales, necessarily adopted to comprise the section in a small space.

display the characters of the strata, and afford abundance of fossil remains. The Lias appears in the Western Isles of Scotland, and on the north-east coast of Ireland. The Upper Lias comprises a thin band of limestone, rich with remains of insects and fish, which has been traced from Somersetshire and Gloucestershire into Northamptonshire and Lincolnshire.*

In the north and south-east of France, and over a large area in Germany, the Lias, with its peculiar fossils, accompanies the Oolite. One species of Gryphite (*Gryphæa incurva, Lign.* 117, *fig.* 6), which is so abundant in the Liassic strata of England, on the Continent forms a limestone (*Calcaire à gryphites*), which, like the Sussex-marble and many other such rocks, is composed of shells cemented together by a calcareous paste. In Wirtemberg the Lias presents the usual characters of that of England, and contains remains of Ichthyosaurs and other reptiles.†

In the valley of the Arve, in Switzerland, the Lias-clays are of great thickness, and, owing to the ancient effects of igneous or metamorphic agency everywhere apparent in the Alps, have a schistose character, strongly assimilating them to the primary slates.

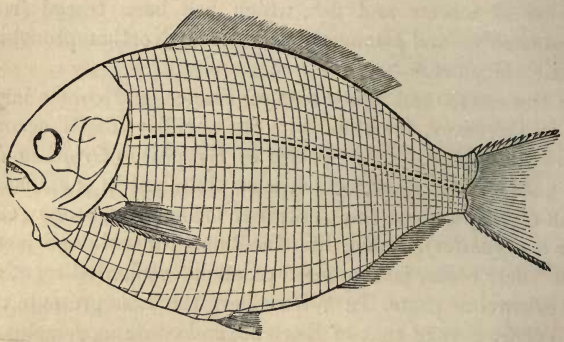
In Russia oolitic deposits cover detached districts, from the Icy Sea to the Caucasus in the south; and in Russia Proper there are shales and sands referable to the Middle or Oxford Oolite; a characteristic species of ammonite (*A. biplex*) of the Portland-rock has been found both in Russia and Poland. In the Himalayas and Central India argillaceous beds occur which contain fossils, which have been regarded as analogous to those of the Lias of Europe.

Bone-bed. — At the base of the Lias, and separating the

* By Messrs. C. Moore, Binfield, Morris, and Brodie: Medals, vol. ii. p. 549. Annals N. H. 2 ser. vol. xix. p. 56.

† See Dr. Jaeger's work, Ueber die fossilen Reptilien, welche in Würtemberg aufgefunden worden sind. Stuttgard, 1828.

lower shales and limestones from the uppermost Triassic bed beneath, there is a layer of coarse detritus, a few inches thick, commonly known as the *Lias Bone-bed*,* from the



LIGN. 125.—RESTORED FIGURE OF THE DAPEDIUS OF THE LIAS.

(One-sixth the natural size By M. Agassiz.)

immense quantities of water-worn bones, teeth, and coprolites of fishes, which it contains. It is, in fact, an aggregation of mud, sand, and the debris of fishes and reptiles. Teeth of fishes of the genus *Ceratodus* (Med. Creat. p. 587), are very frequent in this bed. Aust Cliff, on the Severn, near Westbury, in Somersetshire, is a well-known locality for the fossils of this remarkable deposit. By some geologists this bone-bed is included in the Trias, and by others in the Lias. A similar stratum occupies the same geological position in Germany, and contains organic remains of a like nature.

* Another "bone-bed" occurs in the Upper Ludlow series (Geol. Journ. vol. xi. p. 8); and fish-remains are almost as abundant in a portion of the Mountain-limestone (at Clifton and Armagh), and in the Inferior Oolite at Leckhampton Hill. (See Quart. Geol. Journ. vol. vii. p. 211.)

Considerable interest is attached to the exact determination of the extent of this "bone-bed," and its associated strata, from England to the Eastern Alps. In the west it appears to have been a comparatively shallow-water deposit; but towards the east it is imbedded in other fossiliferous strata that were evidently deposited in a deeper sea. These shelly beds form part of the series termed "Koessen-strata" by the Austrian geologists, and without doubt belong to the Upper Trias. A bone-bed, similar to that underlying the English Lias, occurs near Stuttgard,* and certain sandstone strata there accompanying it are, according to Messrs. Oppel and Suess, the littoral equivalents of the marine "Koessen-strata," so well developed in the Eastern Alps, and characterized to the eastward of Vienna, in the Austrian Salinar district, and even partly in the Alps of Tyrol and Bavaria, by numerous remains of marine animals, especially of Brachiopods and Oysters. In the Vorarlberg, these forms begin to disappear, giving place to Pecten Valoniensis, Cardium Rhæticum, Card. Austriacum, and other pectinibranchiates, indicative of a diminution of the depth of the old sea there. Beyond the overlying strata of more recent date, and along the shores of that primæval sea, these deposits have assumed quite a littoral character; Oysters and Brachiopods having totally disappeared, and the pectinibranchiate molluscs, such as occur in these beds in the Vorarlberg, and some new species, being predominant in the fossil fauna. Hence it is concluded that the "Koessen-beds" are contemporaneous with the ossiferous strata or bone-beds, the existence of which may be traced for a great distance, from the South-west of Germany to France and England.

* The Stuttgard "bone-bed" is famous for having yielded some minute teeth of a Mammalian animal (Lyell's Manual of Geology, 1855, p. 343, and Supplement, 1857). This will be noticed in the chapter on the Trias, the Stuttgard deposits having been referred to that formation.

26. ORGANIC REMAINS OF THE JURASSIC SYSTEM.—The fossils discovered in the Oolitic and Liassic strata amount to many hundred species,* and it is impossible in a work of this nature to give but the briefest summary of these organic remains; it must suffice to offer a few general remarks on the nature of the fauna and flora of the sea and land during the vast period of time which the accumulation of sediments of such extent and thickness must have required.

Vegetable remains.—Some species of fucoidal plants and upwards of a hundred species of terrestrial vegetables have been determined from the Jurassic rocks of Britain. The latter consist of ferns, cycadaceous plants, and coniferous trees; constituting a flora analogous to that which now prevails in the maritime districts of the West Indies, New Holland, and the Cape of Good Hope, &c. A large species of plant allied to the recent Marestail (*Equisetites columnaris*) is abundant in the coal-bearing Oolite; and in Yorkshire so many of these plants occur in an erect position that it is supposed they must have grown on the spots they now occupy: we shall recur to this fact hereafter.

One of the most remarkable fossil vegetables discovered in this formation in England is the fruit of a tree (*Podocarya Bucklandi*, Unger) allied to the Pandanus or Screw-pine, from the lower Oolite of Charmouth in Dorsetshire.†

Fragments of trunks of coniferous trees of the Araucarian type are found throughout the Jurassic formation; and, as we have already stated, the last bed of the Oolite, when

* The student is referred to Prof. Phillips' tables of fossils in the Encyclopædia Metrop., art. *Geology*, to Sir H. De la Beche's Manual of Geology, and to Mr. Morris's British Fossils, for lists of the fossils found in the British Oolite and Lias; and to the beautiful work on the organic remains of the "*Terrains Jurassiques*," by M. D'Orbigny. See also Medals of Creation.

† Dr. Buckland's Bridgwater Treatise, vol. ii. pl. 63.

elevated above the waters, was clothed with pine-forests (vol. i. 400).

The quantity of drift-wood in a carbonized state, but not converted into coal, is very considerable in the argillaceous strata. In the Oxford-clay, at Trowbridge,* masses of wood occur in abundance; oysters, terebratulæ, and other shells are often adherent to the fragments of trunks and branches of trees, which have evidently been drifted from a distance into the bed of the sea. Much of this wood is soft and flexible when first exposed, and, when dry, burns with a bright flame. In the Lias of Whitby, Lyme Regis, and other localities, the wood is often calcareous, and admits of a fine polish: occasionally silicified masses are met with.†

27. ZOOPHYTA AND RADIARIA.—Of corals and moss-corals numerous jurassic species abound. The reefs of coral constituting the Coral-rag have already been alluded to. In some parts of Germany coralline Oolites are largely developed, and all the corals are silicified in certain localities; this is especially the case between Nattheim and Heidenheim,‡ whence exquisite specimens of *Astræa*, *Lithodendron*, &c. have been obtained.

In the beds of chert in the Oolite of Tisbury in Wilts, shells and corals are found in a beautifully silicified state, particularly a species of *Isastræa* (*I. Tisburiensis*). Large silicified masses of this coral are met with, which, on being cut and polished, display the intimate structure of the original, and form an ornamental material for the jewellers and lapidaries. A matchless specimen of the soft parts of a *Trigonia*, transmuted into silex, was obtained from Tisbury by the late Miss E. Benett, and is now, with the greater

* See above, p. 500.

† Beautiful specimens of the fossil wood and plants from the Lias and Oolite are exhibited in the British Museum. *Petrifact.* Chap. I.

‡ Geol. Soc. Journ. vol. vii. part 2, p. 71.

part of the collection of that lady, in the possession of Mr. Wilson of Philadelphia.*

The Crinoidea, or lily-shaped animals, are also abundant, and are often found in an admirable state of perfection. Whole slabs of many of the Lias-shales are covered with Pentacrinites, frosted with brilliant pyrites, and lying in relief on the stone, as if spread out on the sea-sand.†

Of the *Echinoidea* upwards of seventy species, and of Star-fishes nearly twenty genera, comprising many species, have been determined from the British Oolites.‡ Some splendid Star-fishes from the Yorkshire Oolite and Lias are figured in Charlesworth's London Geological Journal, pl. 17 (*Astropecten arenicola*), and pl. 19, 20 (*Ophiodermata*).

FIG. 176.—AMMONITES COMMUNIS; *from the Lias of Whitby.*

28. MOLLUSCA.—The shells, both of testaceous and conchiferous molluscs, amount to many hundred species. Of the *Cephalopoda*, as Nautili, Ammonites, Belemnites, &c., several hundred species, belonging to numerous genera, have been figured and described.§

The state of perfection in which the animals allied to the Cuttle-fish occur in the Lias, and also in the clays of the

* Figures and a description of this extraordinary British fossil have been given by Mr. Charlesworth in the London Geological Journal.

† See Petrifactions, &c., p. 88.

‡ Dr. Wright's Monograph, published by the Palæontographical Society, 1856, furnishes a careful and lucid history of the Jurassic Echinoderms of Britain.

§ See Sowerby's Mineral Conchology, and the works before referred to.

Oolite, especially in the Oxford-clay of Wiltshire,* is most extraordinary. The soft part of the body and arms, the capsule of the globe of the eye, and the ink-bag still retaining its inspissated secretion, are often found in their natural position, and distinctly recognisable. This state indicates a rapid imbedding of the animals while in their natural element.†

29. CRUSTACEANS AND INSECTS.—Numerous genera of Crustaceans and Insects have been collected from the Jurassic deposits: the museum of the late Count Münster was celebrated throughout Europe for the magnificent series of remains of this kind which it contained.

Species allied to the Shrimps, Prawns, Lobsters, and Crabs have been found in great perfection at Solenhofen, Pappenheim, &c.; an extinct form (*Eryon Cuvieri*‡), and some *Limuli*,§ occur in an exceedingly perfect state; and small bivalved Entomostraca are not rare in some beds, though as yet they are undescribed.

A fine fossil Dragon-fly, from Solenhofen, in the cabinet of the Marquess of Northampton, is figured in Medals of Creation (vol. ii. p. 551). In England, the Coal-measures, Lias, Stonesfield-slate, Forest-marble, and Wealden have yielded fossil insects. Among the specimens found in the Lias, is a wing of a very large Dragon-fly, which closely resembles the recent species in the general arrangement of the nervures, and appears not to be separable from the genus *Æshna* (*Lign.* 127). In this fossil an opaque spot (*a*) exists on the anterior margin of the wing, as in most of the living Libellulidæ.

Mr. Brodie has figured and described numerous fossil insects from the Oolite and Lias of England,‖ comprising

* See the London Geological and Palæontological Journal, No. 2, Pl. XV. XVI., for figures of some remarkable specimens in the late Mr. Channing Pearce's cabinet.

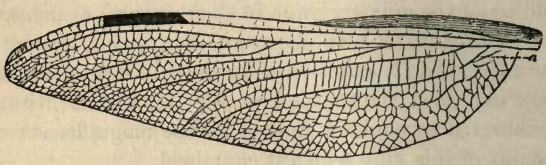
† See Dr. Buckland's Bridgwater Treatise, for exquisite figures of the shells and soft parts of Cephalopoda.

‡ Medals, ii. p. 520.

§ Ibid. p. 522.

‖ History of Fossil Insects (1845), p. xiv. In this work will be found

Coleoptera, Neuroptera, Hemiptera, and Homoptera. The wings of insects allied to the recent genus *Panorpa* have been found in the Lias of Wainlode Cliff, on the banks of the Severn.*



LIGN. 127.—FOSSIL WING OF A SPECIES OF DRAGON-FLY; FROM THE LIAS OF BIDFORD, WARWICKSHIRE. *(Nat. size.)*

a, Spot on the margin of the wing.

(Æshna Liassina, of Mr. Strickland †)

The several hundred specimens of fossil insects that have been discovered in the Lias belong nearly all to forms that inhabit temperate climates, and present a remarkable affinity to existing families; so that in one instance only has Mr. Westwood, the distinguished entomologist, ventured to propose a new generic name.‡ The same fact of the close relationship of the fossil to the recent types of Insecta holds good, with but one or two exceptions, in the case of the insects from the Purbeck beds.

30. FISHES.—All the Fishes of the Oolite are referable to extinct genera, and essentially differ, as a whole, from those

an account of the localities in which insect-remains had been at that time discovered in the secondary rocks of England. See also Dr. Buckland's Bridg. Treatise; and Medals of Creation, vol. ii. p. 547, &c.

* See Medals of Creation, vol. ii. p. 553.

† Mag. Nat. Hist. vol. iv. p. 301. See Nova Acta Car. Leop. Acad. vol. xix. part 1, for Germar's fossil Insects from Solenhofen.

‡ Mr. Strickland, on the results of recent researches into the fossil insects of the secondary formations of Britain: Brit. Assoc. Reports for 1845, p. 58.

of the cretaceous epoch. Teeth, scales, dorsal spines, and other remains of *Hybodus*, *Acrodus*, *Asteracanthus*, *Ganodus*, *Eugnathus*, *Pachycormus*, *Pycnodus*, *Æchmodus*, *Lepidotus*, and *Pholidophorus* are abundant in some of the strata.*

Among the Ichthyolites that prevail in the Lias, the scales and teeth of a genus of Ganoids called *Dapedius* are especially abundant, and entire specimens of the fish are often met with. I am led to notice this genus more particularly, that your attention may be directed to a remarkable modification of structure observable in the Ichthyolites of the more ancient deposits, which will hereafter come under our examination. The Dapedius belongs to that division of the *Lepidoids* which are *homocercal* (equal-tailed) or nearly so;† while all the genera from the palæozoic strata are *heterocercal*, or having tails with unequal lobes.‡ But few of the existing genera of fishes have this latter condition of the caudal fin, while it is found in almost every fossil species below the Triassic deposits.§

31. REPTILES OF THE JURASSIC SYSTEM.—The prevalence of animals of the reptilian class during the Oolitic era was incidentally alluded to in the course of our previous observations on the organic contents of the different members of this extensive formation. From the lowermost stratum, the Bone-bed of the Lias, to the uppermost layer of the Portland-stone, the remains of extinct reptiles have

* See Medals of Creation, vol. ii. chap. xiv. xv.; and Petrifactions and their Teachings, chap. v.

† It is difficult to determine whether some of the Triassic and Liassic Lepidoid fishes are really homocercal or not. Quart. Journ. Geol. Soc. vol. x. p. 368.

‡ See Medals of Creation, p. 575; Petrifactions, p. 421.

§ It is worthy of remark, that in the embryotic state most fishes are heterocercal; and those species which, when arrived at maturity, have the equally-lobed tail attain this homocercal type in the progress of their development. For remarks on the heterocercality of the Salmonidæ, &c., see Mr. Huxley's observations in the "Notices of the Royal Instit." 1855, p. 84.

been found more or less abundantly in every deposit. About forty species, belonging to several genera, have been determined as occurring in the Jurassic strata of the British Islands. These have been carefully investigated and described by Professor Owen, in the Reports of the British Association for 1840 and 1841, and in the Monographs on Fossil British Reptiles published by the Palæontographical Society. Cuvier, Gervais, Hermann von Meyer, Jaeger, Burmeister, and Theodori are amongst the continental naturalists who have studied the fossil reptiles.* As I shall have occasion to recur to this subject in the sequel, it will be sufficient in this place briefly to enumerate the principal kinds hitherto discovered in the Oolite and Lias.

In addition to the reptiles of which remains have been found in the Chalk and Wealden, namely, the Megalosaurus (p. 435), Pœcilopleuron (p. 432), Cetiosaurus (p. 427), Streptospondylus, Pterodactylus, Ichthyosaurus, Plesiosaurus,—and of some of these, especially of the two last-named genera, numerous species abound in the Lias and Oolite,—several other Crocodilian reptiles, with peculiar osteological modifications, also occur. These are the Teleosaurus, Steneosaurus,† &c., which are characterized by their long narrow muzzles, sharp-pointed teeth, short fore-legs, imbricated scales, and doubly concave or flat-faced vertebræ: their relics are chiefly found in the Lower Oolite and Lias.

The most remarkable circumstance relating to the Ichthyosauri and Plesiosauri that swarm in the Lias is the connected state in which all the bones of the skeleton occur. The entire osseous frame-work, from the extremity of the snout to the last vertebra of the tail, often remains entire,

* See Pictet's *Paléontologie*, 2nd Edit. vol. ii., for a *résumé* of our knowledge of fossil reptiles.

† See Medals of Creation, vol. ii. p. 679. These gavial-like reptiles are represented amongst the other extinct animals by life-like models in the Crystal Palace Gardens.

or but very little displaced from its natural position; even the bones of the paddles, with their cartilaginous appendages, are in some instances preserved.* The indigestible portion of the food of these carnivorous marine reptiles (as the scales, teeth, and bones of fishes), and their coprolites, are frequently met with in the abdominal cavity.† These facts show that the carcasses of these animals were imbedded in the soft mud at the bottom of the sea, without having been exposed to the action of the billows, or to long transport by rivers or currents. The Wealden fossils present a striking contrast in this respect; for, although bones of Plesiosauri are by no means uncommon in that formation, they are isolated and generally water-worn.

In the Kimmeridge Clay, the relics of a very large marine saurian, allied to the Plesiosaurs, but distinguished by certain osteological characters, have been met with: this extinct reptile is named Pliosaurus. Bones of Flying-Saurians, or Pterodactyles, occur more abundantly in the Oolite and Lias than in any other series of deposits; more than twelve species have been found in the Solenhofen and other Bavarian quarries. In the Stonesfield-slate the bones of one species (*Pterodactylus Bucklandi*), and in the Lias of Lyme Regis, a considerable part of the skeleton of another (*P. macronyx*), have been discovered. The Mammalia of Stonesfield have already been noticed (p. 508).

The general character of the Jurassic or Oolitic formation, as derived from its organic remains, is therefore that of a series of oceanic deposits, accumulated in a depression of great extent, through a period of immense duration. The sea teemed with marine invertebrate animals, belonging to genera and species most of which became extinct before the

* See Medals of Creation, vol. ii. p. 669.

† Consult Dr. Buckland's Bridgwater Treatise, p. 198; and Geol. Trans. 2 ser. vol. iii. p. 223.

Tertiary epoch; and with these were associated multitudes of peculiar Fishes and Reptiles. The dry land, as attested by the remains drifted into the basin of the sea, was inhabited by a few reptiles and marsupial mammals, and was clothed with tree-ferns, cycadeous plants, and coniferous trees; and insects, pterodactyles, and possibly birds,* flew above its surface.

* The Rev. Mr. Dennis's microscopical evidences (Microscop. Journ. vol. v. p. 63) only require further patient investigations to substantiate the fact of the existence of Birds' remains in the Stonesfield slate. The same observant naturalist has brought forward very probable evidences of the mammalian character of some bones from the "Lias Bone-bed" of Lyme Regis (*ibid.* vol. iv. p. 261).

LECTURE V.

PART II.—THE TRIAS AND PERMIAN FORMATIONS.

The Trias and Permian Formations. 2. Geographical Distribution of the Trias and Permian. 3. Rock-Salt and Brine-Springs. 4. Origin of Rock-Salt and Gypsum. 5. The Cheltenham Waters. 6. Conglomerates of the Trias. 7. Organic remains of the Trias. 8. Crustacea, Mollusca, and Crinoidea. 9. Fishes of the Trias. 10. Reptiles of the Trias. 11. The Labyrinthodon. 12. The Rhynchosaurus. 13. The Dicynodon of Africa. 14. Foot-prints on stone. 15. Ornithichnites. 16. Triassic Mammal. 17. The Permian System. 18. Magnesian limestone or Zechstein. 19. Permian of Germany and Russia. 20. Organic Remains of the Permian System. 21. Invertebrata of the Permian. 22. Fishes of the Permian. 23. Reptiles of the Permian. 24. Reptiles. 25. Chelonians or Turtles. 26. Crocodiles. 27. Enalio-saurians or Marine Reptiles. 28. The Plesiosaurus. 29. Pterodactyles, or Flying Reptiles. 30. Ophidians and Batrachians. 31. Review of the Age of Reptiles. 32. Objections considered. 33. Concluding Remarks.

1. THE TRIAS AND PERMIAN FORMATIONS.—Beneath the Lias there is a series of strata, many hundred yards in total thickness, which was formerly known in geology as the *New Red Sandstone Formation*, and divided into two groups, namely the Upper and the Lower. But later investigations * having shown, that, of the fossils found in the lowermost group, scarcely a species is known in the upper series, nor in any newer strata, this system is now separated, under the name of "Permian," from the former, and regarded as the uppermost or terminal group of the *Palæozoic* or primary series; while the Upper New Red is ranked as the lowermost of the *Mesosoic* or secondary formations.† The name of *Trias*, or Triassic System, by which the Upper New Red is now distinguished, relates to the well-marked triple sub-

* See Phillips's "Manual of Geology," 1855, p. 246, 247

† See the "Synoptical Arrangement," p. 203.

division of this series in Germany, and has been adopted to avoid confusion from the restricted application of the old term. The New Red Sandstone series has also been termed the "Pœcilitic" from the variegated colours of its component strata; and "Saliferous," on account of the immense beds of rock-salt which alternate with the red marls in Cheshire and other parts of England. The following table shows the characters and order of succession of the principal Triassic and Permian deposits:—

THE TRIASSIC OR NEW RED FORMATION.

(*Comprising the Keuper, Muschelkalk, and Bunter-Sandstein, of the German geologists.*)

1. Variegated, red, blue, greenish, and white marls or clays (with gypsum and immense beds of rock-salt in some places), interstratified with sandy beds; the sandstones towards the bottom, called "Water-stones," constituting a well-defined band.

[These marls and sandstones attain a thickness of about 1000 feet, and are equivalent to the "Keuper;" the "Muschelkalk" being possibly represented by the "white beds" or "waterstones."]

2. Red and variegated sandstones and marls.
3. Coarse red sandstones and conglomerates.
4. Red and variegated sandstones and marls.*

[Nos. 2, 3, and 4 collectively have a thickness of more than 1000 feet.]

THE PERMIAN OR MAGNESIAN-LIMESTONE FORMATION.

(*Comprising the Bunter-Schiefer, Zechstein, Kupfer-Schiefer, and Roth-todt-liegendes,† of the Germans.*)

1. Reddish sandstones, and red and white gypsiferous marls, with thin limestone-beds. (About 200 feet thick).
2. Magnesian limestone (*Zechstein*); white, red, or yellowish magnesian limestone, sometimes concretionary, sometimes brecciated, in thick beds, with marine organic remains. (About 500 feet thick.)

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* See Quart. Journ. Geol. Soc. vol. ix. p. 188, for Prof. Ramsay's account of the four subdivisions of the English "Bunter."

† *Roth-todt-liegendes*, signifying "red dead layer," is a German mining term, denoting that the copper of the upper beds has died out, this layer not being metalliferous.

3. Marl-slate and limestone, in thin layers, containing fishes and sea-shells. (About 60 feet thick.) The *Kupfer-Schiefer*, or Copper-schist, of Mansfeld.
4. Variegated marls, sandstones, and conglomerates (Pontefract Rock) of variable thickness and character.* (About 200 feet thick.)

From this tabular view, the Trias and Permian systems are seen to consist of red and variegated marls, generally gypsiferous, sandstones, magnesian limestones, and conglomerates, more or less coloured with peroxide of iron; the upper group containing beds of salt and gypsum; and the lower, calcareous rocks, having in their composition a large proportion of magnesia. As a whole, the strata are comparatively poor in organic remains; but in some localities land-plants, marine shells, and reptiles are met with; certain species and genera being peculiar to each system. The fossils of the Permian rocks are very closely allied in their zoological characters to those of the coal-formation; the organic remains of the Trias, on the contrary, are very distinct, having closer relations to those of the secondary formations, especially the Lias.

2. Geographical Distribution of the Trias and Permian.—For the sake of conciseness I shall comprise both systems in the following brief notice of their geographical distribution.†

From the River Tees to the Tyne (*see the map*, Pl. I. p. 474), these rocks form the Durham coast. The line of the emergence of the New Red from beneath the Lias through Yorkshire to the south-west forms its eastern boundary. Traversing Yorkshire and Nottinghamshire as an irregular band varying from 10 to 30 miles wide, the New Red is accom-

* The sands and sandstones beneath the marl-slate in Durham are believed by Mr. R. Howse not to belong to the Permian series, on account of their unconformability, and their being characterized by genuine carboniferous species of plants and fish. Annals N. H. 1856.

† In the map, Plate I. the Trias and Permian are both denoted by the same colour and number (5).

panied by a still narrower band of Permian rocks to the west as far as Nottingham, from whence as far as Warwick and the vale of the Severn * to the south-west, and to Shrewsbury and the Lancashire coast on the west and north-west, the New Red spreads out irregularly, comprising the rich salt-fields of Cheshire and Worcestershire, and surrounding or bordering on the several coal-fields of the Midland counties, Flintshire, and Lancashire, each with its irregular selvedge of Permian strata. In Somerset and Devon the New Red accompanies the Lias. It also forms the vale of the Clwyd in North Wales, and that of the Eden in Cumberland, where it is uniformly bordered with Permian rocks. The latter occur also in an isolated patch in Anglesea,† and are represented in the South-western counties by conglomeratic beds near Bristol, on the sides of the Mendips, and near Exeter.

The New Red of Cumberland is continuous with the sandstone area of South-eastern Dumfriesshire; but the red sandstones of the upper part of Annandale (Corncockle Muir, Moffat, &c.), and of Dumfries and the vale of the Nith, are referred by Messrs. Binney and Harkness ‡ to the Permian series. In Ireland, Permian fossils have been found at Cultra,§ near Belfast, and at Artrea,‖ and Roan Hill, Tyrone.¶ The great breadth of the district of which the Triassic beds form the subsoil, in their western expansion, arises from the New Red marls and sandstones of the North-western and the Southern counties being nearly horizontal beds, for the most part free from overlying deposits, and succeeding to the disturbed underlying strata, which had previously been thrown up, at various and often considerable angles, into lofty groups and chains of hills, which appear like so many islands amidst the great plain of Red-marl (see section of the Mendips, p. 522).**

On the Continent, the Triassic and Permian groups, with occasional variations in the strata, may be traced nearly opposite the Devonshire coast, skirting the palæozoic rocks of Brittany; and

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* A valuable paper by Murchison and Strickland on the "New Red of Gloucestershire," &c. will be found in Geol. Transact. 2nd series, vol. v. p. 331. See also Murchison's *Siluria*, p. 300, &c.

† Lately noticed by Professor Ramsay, Local Director of the Geological Survey.

‡ Quart. Geol. Journ. vol. xii. p. 138, and p. 254.

§ Journ. Geol. Soc. Dublin, vol. i. p. 175. ‖ *Ibid.* vol. vii. p. 67.

¶ Geol. Proc. vol. ii. p. 206; Portlock's Report, Londonderry, p. 468; and Quart. Geol. Journ. vol. iii. p. 4.

** See also the map of the Mendips in De la Beche's Geological Observer, p. 478.

to the South-east, underlying the Jura-limestone, and containing beds of gypsum and salt, they occur in patches on the flanks of the gneissic area of Central France. They have a great extent in Central Germany, stretching from the Hundsrück to the Vosges on the west of the Rhine Valley, and from the Hartz to the Black Forest on its eastern side. They are traceable also as a zone on either side of the Alps. In Saxony, Silesia, and Poland there are isolated tracks of these strata, but they prevail in the north and east of European Russia; the great extension of the Magnesian limestone series over and around the Government of Perm having suggested to Sir R. Murchison the present geological name of this formation. Triassic rocks are known in several parts of Spain and Portugal.*

The Trias of Germany, distinct in its triple character, is well developed in Bavaria and Wirtemberg. Immediately beneath the Lias is the series termed the *Keuper*,† which consists of variegated red and green marls and sandstones, containing intercalations of salt and gypsum, as in England, and some coaly beds. This group is superimposed on a fine cream-coloured "shell-limestone," or *Muschelkalk*, which abounds in organic remains; especially in that beautiful extinct crinoidean, the *Lily encrinite* (*Lign.* 131), which is exclusively found in this bed, and chiefly near Brunswick: the Muschelkalk is not known to occur in England. The lowermost series of the Trias is the *Bunter-Sandstein*,‡ consisting of variegated sandstones and marls, resembling those of the Keuper. The lower portion of the Bunter (Bunter-Schiefer) has been separated from this group to be allocated to the Permian series.§

In the United States of North America red sandstones and shales, usually referred to the Trias, occupy the lower part of the valley of the

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* The Geological Map of Europe, by Murchison and Nicol, is a good guide for the student in studying the extension of these and other formations.

† In Western Europe the junction-beds between the Lias and the Keuper appear to be a thicker development of the "Bone-bed," associated with some shelly bands. Towards the East, these are found to be of more and more importance, until, in the Austrian Alps, they thicken out into several distinct beds, locally known as Koessen-beds, Dachstein-beds, Hallstatt-beds, St. Cassian-beds, Guttenstein-beds, and Werfen-beds.

‡ Variegated or spotted sandstone.

§ See Murchison and Morris on the Permian rocks of Thuringia and the Hartz, Quart. Journ. Geol. Soc. vol. xi. p. 426.

Connecticut, and are continued into New Jersey, Maryland, Virginia, and North Carolina, and similar strata occur on each margin of the Bay of Fundy and in Prince Edward Island. These red sandstones are associated in some places with coal-bearing shales, sometimes abounding in plant-remains and fishes which comprise forms both of palæozoic and secondary types. The Connecticut sandstones are invested with an extraordinary degree of interest, from the abundance and variety of the foot-prints of unknown animals with which the surface of some of the laminated sandstones are impressed; a phenomenon we shall presently examine.

Some traces of Permian rocks have been detected in Spitzbergen, and Muschelkalk-fossils have been detected by Capt. R. Strachey in the Himalayas.*

3. ROCK-SALT AND BRINE-SPRINGS OF THE TRIAS.—In England and Ireland (Carrickfergus),† the Trias is the chief repository of salt or chloride of sodium: and brine-springs, which are subterranean streams of water impregnated with salt from percolating through saliferous strata, are abundant in the great plain of the red marls and sandstones of Cheshire. The salt, however, is not uniform in extent, but occupies limited areas.

The saliferous strata of Northwich present the following series:—

	Feet.
1. Uppermost calcareous marl . . .	15
2. Red and blue clays	120
3. Bed of rock-salt	75
4. Clay, with veins of rock-salt . .	31
5. Second bed of rock-salt	110

Droitwich, in Worcestershire, which is situated nearly in the centre of the county, has been celebrated for the production of salt from its brine-springs, from the time of the Romans; and this inexhaustible fountain of saline water has continued ever since flowing up, and yielding salt in

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* Quart. Geol. Journ. vol. vii. p. 305.

† Two beds of rock-salt, underlying upwards of 630 feet of red gypsiferous marl, and making together a thickness of more than 120 feet, were discovered at Carrickfergus by the enterprise of the Marquis of Downshire. (Jukes, Geology, p. 245.)

undiminished quantities.* It is probable that the manufacture is coeval with the town itself; but it was not until the year 1725, that the strong brine for which it is now famous was discovered; from one spring alone, the enormous quantity of a thousand tons of salt have been obtained per week.†

At a distance of from thirty or forty feet below the surface there is a bed of hard gypsum, about 150 feet thick; through this a small hole is bored to the river of brine, which is in depth about twenty-two inches, and beneath which is rock-salt. The brine rises rapidly through the aperture, and is pumped into a capacious reservoir, whence it is conveyed into iron-boilers for evaporation: it is supposed to be stronger than any other in the kingdom, and contains above one-fourth part its weight of salt. One of the shafts is sunk to a depth of nearly 500 feet, and passes through four layers of salt, 85 feet in aggregate thickness. Some of the beds of salt in Cheshire are from 70 to 120 feet thick. A red sandstone, containing vegetable remains, forms the foundation-rock of the saliferous deposits of England.‡

4. ORIGIN OF ROCK-SALT.—The origin of these enormous subterranean beds of rock-salt is as enigmatical as that of the saltness of the waters of the ocean. But deposits of salt, though prevailing in England and the Continent in the formation under examination, are not confined to any particular group of strata. The celebrated salt-mines of Galicia (see p. 289), and numerous salt-works in Persia and Western Asia, are made in tertiary strata; § while in the State of New York salt and gypsum, with variegated marls, are

* The Romans imposed a tax on the Britons who worked the Droitwich salt-mines, and made salt a part of the pay of their soldiers' *salarium*, or salary. Hence the custom of asking for salt at the Eton Montem.—*Geology of England and Wales*, p. 282.

† From Mr. R. Hunt's Report in the Mining Records we learn that the quantity of white salt manufactured from brine in the districts of Wansford and Northwich (Cheshire) in 1855 was 834,514 tons; at Droitwich and Stoke (Worcestershire), 170,000 tons.

‡ For an interesting account of the salt-works at Droitwich, see Mr. Hugh Miller's "Impressions of England and its People," p. 179.

§ According to Dr. A. Fleming, the saliferous beds of the Salt-Range in the Punjaub are of the Devonian age.

found in the Silurian system.* It is to be remarked, that deposits of chloride of sodium are almost always accompanied with layers and intercalations of gypsum; and the circumstance of two powerful acids, the sulphuric (in the gypsum or sulphate of lime), and the hydrochloric (in the chloride of sodium), being so largely and uniformly present, seems to indicate a common origin; both occur abundantly as volcanic products. In a more advanced state of chemical science, this fact may probably tend to the elucidation of the question under consideration.†

The gypsum associated with rock-salt is considered by several eminent observers to be anhydrous, that is, entirely free from water, before exposed to moisture. The great beds of gypsum that occur with rock-salt at Bex, in Switzerland, were found by M. Charpentier to be anhydrous when laid open to the atmosphere. Hence Mr. Bakewell suggests that the consolidation of the salt and gypsum must have been effected in such cases by heat, for there is no conceivable mode of aqueous deposition that could form

* In the middle of the horizontal Silurian rocks of the State of New York, there is a formation of red, green, and bluish-grey marls, with beds of gypsum and occasional salt-springs, the whole being from 800 to 1000 feet thick, and undistinguishable in mineral character from parts of the Trias of Europe.—*Lyell's Travels in America*, p. 54. See also J. Hall's "Geology of New York," 4to, 1843, for notices of the salines and gypsum in the Medina and the Onondaga rocks.

† In treating of the gypsiferous rocks that overlie the nummulitic series in Turkey and Persia, Mr. W. K. Loftus has suggested that volcanic action, suddenly altering the level of the sea-bed and discharging sulphuric vapours into the sea, might have caused the deposition of the gypseous beds, by the chemical change of the calcareous matter held in solution in the water; and that the usual absence of animal remains in such deposits might be similarly accounted for. Mr. Loftus also refers to volcanic agency as the probable cause both of the formation of the rock-salt of the Plain of Khoi (about 80 miles south of Ararat), and of the excessive saltness of the Lake Urumia. Quart. Geol. Journ. vol. xi. pp. 268, 307, and 309.

anhydrous gypsum.* The red colour of the salt and marls is occasioned by oxide of iron, which may have been derived from decomposed volcanic rocks.

That many of the deposits of salt may have originated simply from the evaporation of sea-water pent up in lagoons, lakes, or inland seas, is a generally received and not improbable supposition; but the absence of marine organisms of any kind has been regarded as a formidable objection to this hypothesis.† Another difficulty presents itself in the enormous thickness of many of the beds of salt; which, if considered as the solid residuum of sea-water, must have required a body of fluid inconceivably great; unless we suppose the seas of those ancient periods to have contained a much larger proportion of saline ingredients than the present,—an inference for which there are no reasonable grounds whatever. If we imagine successive subsidences of a given area to have taken place, the alternations of beds of marls with layers of salt of variable thickness may be explained; but the difficulties above mentioned remain in full force. As gypsum ‡ and the chlorides of sodium are often sublimed from volcanic vents, an igneous origin has been ascribed to many of the beds of salt and sulphate of lime. Gypsum is unquestionably, in many instances, a metamorphosed substance; for sulphurous fumes, acting on beds of clay containing shells, convert the lime into selenite; and, acting on limestone, convert it into fibrous and compact gypsum. Many tertiary gypseous deposits have evidently originated from this cause: but crystals of gypsum are also abundantly found in

* Mr. Bakewell's "Introduction to Geology" (5th edit. p. 289) contains an interesting review of this problem, and an account of the most important deposits of salt.

† It cannot, however, be with certainty determined, whether the absence or paucity of fossils in a deposit is owing to an actual reduction of the amount of life in the seas of a given area, or to the mineral character of the strata not having been favourable to the preservation of organic remains.

‡ Gypsum, or sulphate of lime, consists of sulphuric acid, 46·31; lime, 32·90; and water, 20·79. The massive gypsum is called *Alabaster;* the transparent gypsum, *Selenite;* powdered calcined gypsum forms *Plaster of Paris.* The fibrous gypsum has a silky lustre, and is used for ear-rings, brooches, and other ornaments. Fibrous gypsum of great beauty occurs in Derbyshire: veins and masses of this substance abound in the red marls bordering the valley of the Trent.

beds containing pyrites, from the decomposition of the sulphide of iron, and the formation of sulphate of lime from the action of the liberated sulphuric acid on the calcareous materials.* In many parts of Sicily, vapours charged with sulphuric acid are constantly emanating from vents or fumaroles, as they are termed, and throw down large deposits of sulphur and gypsum ; and the fumes of sulphur and boracic acid escape in such quantities, that the peasants put pots, and often bee-hives, over the fumaroles, and thus collect abundance of sulphur and boracic acid. In Tuscany, boracic acid is obtained from jets of vapour which force their way through secondary rocks in contact with serpentine.†

The connexion between volcanic action and the formation of gypsum seems also pointed out by the fact, that in North America, where volcanic rocks are not associated with the coal-measures, there are no beds of gypsum: but in Nova Scotia, where igneous rocks are interpolated beneath the coal, there are extensive gypseous deposits. Sir C. Lyell, after a careful review of the phenomena exhibited by these gypsiferous strata, expresses his conviction, that the production of gypsum in the Carboniferous sea was intimately connected with volcanic action, whether in the form of stufas or heated vapours, or of hot mineral-springs, or some other effects of sub-marine igneous eruptions.

It may be also remarked, that the variegated appearance of the marls —red, pink, blue, yellow, dun, &c.—of the Trias, seems to have been produced by the chemical effects of vapours or fluids charged with sulphuric or chloric acid; at least the same change is induced on the tertiary marls of the Lipari Isles by the gaseous emanations and vapours of the fumaroles and hot springs.

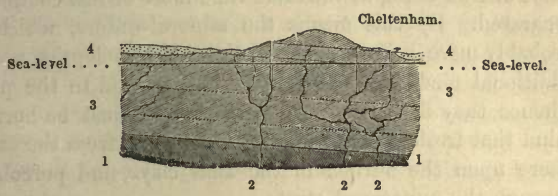
5. THE CHELTENHAM WATERS.—In certain localities where the marls of the Trias are covered by other beds, and the saline springs force their way to the surface through the superincumbent deposits, chemical changes take place in these solutions of chloride of sodium, which thus acquire

* See Mr. Morris's paper in Mag. Nat. Hist. 1838, p. 43. Recent railway-embankments of shelly clays (such as the London, Kimmeridge, and Oxford Clays) often exhibit this phenomenon, and are liable to give way from their consolidation being thereby prevented.

† See a highly interesting Memoir on the Geology of some parts of Tuscany, by W. J. Hamilton, Esq., Quart. Geol. Journal, vol. i. p. 274; also Sir R. Murchison's description of the Tuscan fumaroles and soffioni, Quart. Geol. Journ. vol. vii. p. 367.

other properties, and become what are termed mineral-waters; such is the origin of the celebrated Cheltenham waters.*

The town of Cheltenham is built on Lias clays and marls, beneath which, but at a great depth, lie the Triassic deposits, the reservoir of the rock-salt and brine-springs, whence the mineral waters have their origin, and derive their saline ingredients; but these undergo various modifications in their passage to the surface through the superincumbent beds of Lias, which are full of iron-pyrites, and sulphate of lime. "From the analyses of these waters by



LIGN. 128.—DIAGRAM-SECTION OF THE STRATA BENEATH CHELTENHAM.

(From Sir R. I. Murchison's Sil. Syst.)

1, 1, Red marl. 2, 2, 2, Origin of the Cheltenham Waters. 3, 3, Lias clays and marls. 4, Alluvium.

several chemists, it appears that their principal constituents are the chloride of sodium, or sea-salt, and the sulphates of soda and magnesia; sulphate of lime, oxide of iron, and chloride of magnesium being present in some wells only, and in much smaller quantities. . . . . Besides these ingredients, *iodine* and *bromine* have been detected by Dr. Daubeny, who endeavoured to ascertain whether these two active princi-

* See Sir R. I. Murchison's description of the mineral-springs of Gloucestershire and Worcestershire, "Silurian System," p. 34; and in his "Geology of Cheltenham," 2nd edit. p. 63. The Lias and Trias of this district are described in full detail in the *Sil. Syst.* pp. 16, &c.

ples, which the French chemists had recently discovered in modern marine productions, did not also exist in mineral salt waters issuing from strata which geologists consider to have been formed beneath the sea."

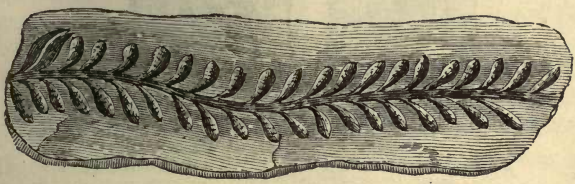
As the saline springs of the red marls rise up through the Lias (*Lign.* 128), they undergo certain chemical changes. From the decomposition of the sulphate of iron which takes place, a vast quantity of sulphuric acid must be generated, which, reacting on the different bases of magnesia, lime, &c., contained in the strata, forms those sulphates so prevalent in the higher or pyritous beds of the Lias; the oxide of iron being at the same time more or less completely separated. By this means the mineral-waters, which are probably mere brine-springs at the greatest depths, acquire additional medicinal qualities as they ascend to the places whence they flow. At the same time it must be borne in mind that fresh water is continually falling from the atmosphere upon the surface of the Lias clays, and percolating through the uppermost strata.

6. CONGLOMERATES OF THE TRIAS.—The conglomerates of this formation are chiefly composed of pebbles and detritus derived from the destruction of igneous and metamorphic rocks, as slate, quartz-rock, granite, porphyry, &c.; and the fine siliceous sandstones contain a large proportion of such debris. It would, therefore, appear that the sea which deposited the saliferous group was bounded by the rocks of whose ruins it is composed; in like manner as the existence of beaches of flint-pebbles evinces the destruction of former chalk-cliffs.

The rock on which Nottingham Castle is built is a conglomerate formed of the ruins of the ancient rocks of the neighbouring districts. The rounded pebbles of quartz, lydian stone, granite, jasper, porphyry, slate, &c., seem to have originated from rocks formerly connected with the range of Charnwood Forest. Still nearer the Charnwood

hills, the finest sandstone contains fragments of slate. Mr. Bakewell was of opinion that a large proportion of the materials of the Triassic strata was derived from trap and other igneous rocks; and that the red marl was the debris arising from the decomposition of the less indurated volcanic products; hence, probably, the extreme fertility of the soil.*

7. Organic Remains of the Trias. — This formation presents a remarkable contrast with that of the Jurassic, in the paucity of organic remains; for, while the latter teems with marine fossils, the former, throughout immense areas, is almost wholly destitute of any vestiges of animals or vegetables; a proof that the strata were, for the most part, accumulated under conditions unfavourable for the preservation of organic structures. Several Fucoidal plants, between thirty and forty species of Ferns,† nearly twelve of Cycadeæ, and about fourteen referable to Coniferæ, have, however, been obtained and determined. Among these are fronds of a plant bearing some resemblance to the



Lign. 129.—Fossil plant allied to the adder's-tongue; from the red marl, Sulz-les-bains.

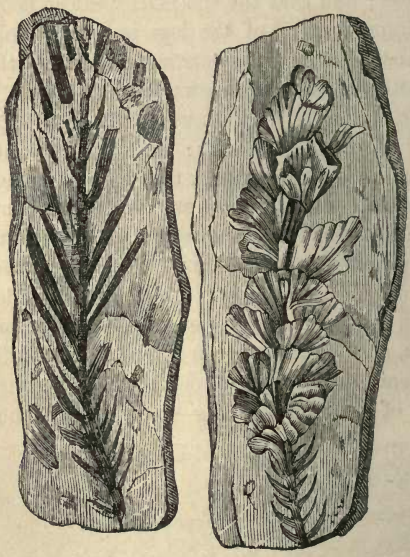
(*Crematopteris scolopendrioides; one half the natural size.*)

Adder's tongue (*Asplenium scolopendrium*), so common on the banks of our woods and copses; a specimen discovered by M. Voltz exhibits the fructification on the back of the leaf (*Lign.* 129). But the most characteristic plants of

* Introduction to Geology, fifth edition, p. 279.

† Fragments of the large fronds of the *Anomopteris Mougeoti*, from the Bunter, are figured in the *Medals*, vol. i. p. 117, and *Petrifactions*, p. 32.

the Triassic flora are Coniferæ, belonging to a genus named *Voltzia*,* which differ from any now living, but somewhat resemble the Araucaria, or Norfolk Island pine. Fragments



1 2

LIGN. 130.—CONIFERÆ OF THE TRIAS: FROM SULZ-LES-BAINS.

Fig. 1. Voltzia longifolia.
— 2. —— heterophylla; with the fructification.

of these fossil plants are frequent in the greenish marls near Strasburg: two specimens of portions of branches are figured in *Lign.* 130; *fig.* 2 shows the fructification.† Several

* From the late Mr. Voltz of Strasburg, by whom they were first discovered.

† See Essai d'une Flore du Grès Bigarré; par M. Ad. Brongniart, Ann. Sciences Nat., 1828.

species of equisetaceous plants (*Calamites* and *Equisetites*) abound; one of which is probably the *E. columnaris* of the Lower Oolite.

A very remarkable fossil (*Dictyophyllum crassinervum**) has been found in the Triassic sandstone near Liverpool; it is a leaf of considerable size, bearing a striking resemblance to the foliage of some of the thick-ribbed cabbages.† I will only add, that, as a whole, the flora of the Trias, or New Red, presents a general character by which it is separated alike from the vegetation of the older formations below, and of the Lias above, though showing a strong affinity to that of the latter.

8. CRUSTACEA, MOLLUSCA, AND CRINOIDEA.—Crustaceans are rare in the Trias, with the exception of one genus of small bivalved entomostracans, allied to the recent *Estheriæ*, and commonly confounded with the molluscan *Posidonomyæ*. This little *Estheria* (*Posidonomya minuta*) is characteristic of the Keuper deposits of England and the Continent; and similar fossils occur in the red shales of Virginia and Pennsylvania.‡ M. Schimper§ has figured and described some Xiphosures or Limulus-like Crustaceans from the Trias of Alsace. Polypiferous zoophytes or corals, which are so abundant in the Jurassic formation, are very rare in the Trias.‖ The shells comprise a few species of Cardium, Trigonia, Mya, Plagiostoma, Ostræa, Pecten, Avicula, Terebratula, and other Bivalves, with several Gasteropoda, some Nautili, and numerous Ammonites and Ceratites.¶ The Radiaria consist

* The "thick-nerved net-leaf."

† Lindley's Foss. Flora, pl. 201, and Murchison's, "Silurian System," p. 43.

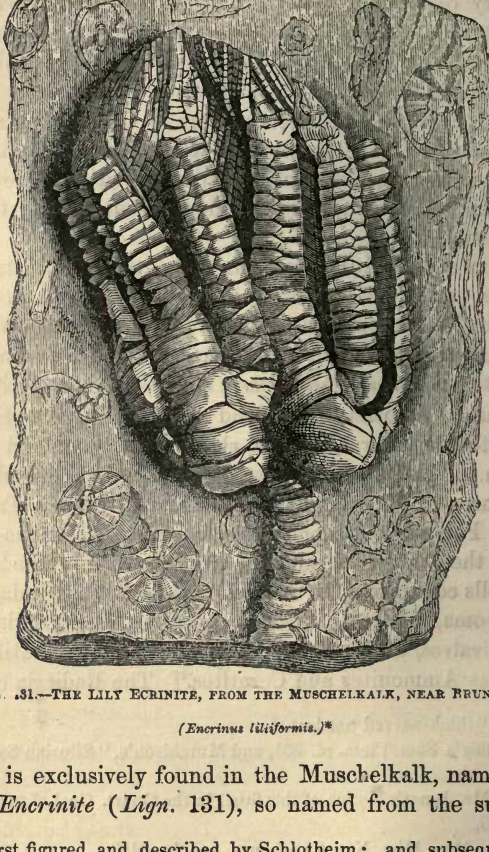
‡ See Mr. Jones's Notice of this fossil in the Quart. Geol. Journ., vol. xii. p. 376.

§ Mém. Mus. Hist. Nat. Strasbourg, vol. iv. 1853.

‖ One or two species occur in the Muschelkalk, and two in the Hallstatt-beds, of the Austrian Alps; Denksch. Akad. Wien, vol. ix. p. 167.

¶ Medals, vol. ii. p. 483.

of a few Star-fishes, Cidarides, Pentacrinites, and Encrinites. Of the latter, a most beautiful form of this family of Crinoi-



LION .31.—THE LILY ECRINITE, FROM THE MUSCHELKALK, NEAR BRUNSWICK.

*(Encrinus liliiformis.)**

deans is exclusively found in the Muschelkalk, namely, the *Lily Encrinite* (*Lign.* 131), so named from the supposed

* First figured and described by Schlotheim; and subsequently, as *E. moniliformis*, by Miller. Baron von Strombeck has written an interesting description, with illustrations, of the deformities of this species in the "Palæontographica," vol. iv. p. 169.

resemblance of the animal, when in repose, to a closed lily: in the lecture on Zoophytes, &c., I shall describe this elegant fossil more particularly: the specimens hitherto obtained are from the neighbourhood of Brunswick.

9. Fishes of the Trias. — The bone-bed that intervenes between the Lias and Trias (see p. 524), contains teeth and dorsal rays of numerous small fishes of the genera *Acrodus*, *Ceratodus*, *Gyrolepis*, *Hybodus*, *Nemacanthus*, and *Saurichthis;* similar remains occur, although but rarely, in the sandstones and conglomerates.* Only one species † of the Palæoniscus, a genus of fishes common in the Permian and Carboniferous formations, has been identified in the Trias.

10. Reptiles of the Trias.—The Triassic strata not only contain teeth and bones of several remarkable reptiles, but also bear the foot-marks, or imprints of the feet, of many animals, both biped and quadruped, of whose existence no other traces have, as yet, been discovered. Although the true geological position of some of the strata bearing such imprints is somewhat doubtful (for some geologists question whether a great part of the so-called New Red of North America may not be referable to the Permian group), whilst others associate it with the Jurassic series, it will be convenient to notice the phenomena in question in this place; I will, therefore, first describe the reptilian remains, and afterwards examine the fossil foot-marks.

Bones of several species of Ichthyosaurian and Plesiosaurian reptiles have been found in the Triassic strata of Wirtemberg by Dr. Jaeger of Stutgard. But the most extraor-

* Fish-teeth and Ichthyodorulites have been found in the conglomerate of the Keuper at Pendock, by the Rev. Mr. Symonds (Quart. Geol. Journ. vol. xi. p. 451); and in the gritty sandstone near Warwick, by the Rev. Mr. Brodie (*Ibid.* vol. xii. p. 374). A very peculiar and homocerque fish (*Dipteronotus cyphus*) has been figured and described by Sir P. Egerton from the Bunter-sandstone of Bromsgrove. (*Quart. Geol. Journ.* vol. x. p. 367).

† *Palæoniscus superstes*, Egerton; Geol. Proceed. June, 1857.

dinary reptilian remains discovered in that country and described by the same eminent physician, H. von Meyer, and Burmeister, belong to enormous Sauro-batrachians, or animals allied both to Crocodilians and the Frog-tribe. The principal fossils consist of portions of the cranium, jaws with numerous teeth, and an occipital bone, with a double articulating surface, — a proof of its batrachian affinity. Teeth, portions of the skull and jaws, and a few other bones, of similar extinct Sauro-batrachian or Labyrinthodont reptiles have also been found in Warwickshire, and have been described by Professor Owen.

11. THE LABYRINTHODON.*—The teeth of the gigantic reptile of Wirtemberg † (some of which are two inches long), and those from Warwickshire,‡ are of a gently curved conical shape, and possess a remarkable complicated character, produced by the convergence of numerous labyrinthine folds of the external layer of cement towards the pulp-cavity; and within these inflections the dentine, or tooth-ivory, is similarly disposed. Transverse sections, therefore, display the most beautiful interfoldings of the two substances; and, as the fossils are generally deeply coloured by iron or manganese, they exhibit, under a slightly magnifying power, an extremely interesting appearance; § this peculiarity of organization suggested the name assigned to this peculiar genus of fossil reptiles.

From the structure of the cranium, it appears that the Labyrinthodon, of which there are six English species, had subterminal nostrils leading to a

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* Medals of Creation, vol. ii. p. 741.

† Dr. Jaeger gave the names of *Salamandroides* and *Mastodontosaurus* to the Labyrinthodont animal of Wirtemberg.

‡ According to Prof. Ramsay (Journ. Geol. Soc. vol. xi. p. 198), some at least of the Labyrinthodont remains found in Warwickshire occur in Permian, and not Triassic strata.

* Medals of Creation, vol. ii. p. 744, Pl. VI. fig. 3. See Prof. Owen's

wide and shallow nasal cavity, separated from the cavity of the mouth by a broad and almost continuous horizontal palatal flooring. It is, therefore, inferred that these reptiles breathed air like the crocodiles, and were probably furnished with well-developed ribs: thus these early representatives of the Batrachians belong to a higher condition of structure than any true Batrachia now known to exist.* These gigantic Sauro-batrachians must have borne the same relation in magnitude to the diminutive existing members of the frog-tribe, as the extinct colossal Mosasaur and Iguanodon to the recent Monitors and Iguanas.†

Cladyodon. — Several detached, pointed, trenchant, recurved teeth, the crowns of which are an inch long, and five lines broad at the base, have been found in the Warwickshire sandstone. They closely agree with the teeth of the Thecodont reptiles of the Permian; but Professor Owen regards them as generically distinct, and has named the reptile to which they belonged the *Cladyodon*.‡

12. RHYNCHOSAURUS.—The New Red sandstone quarries at Grinsill, in Warwickshire, have yielded the remains of a very anomalous modification of reptilian organization, combining the lacertian type of skull with edentulous jaws. The general aspect of the cranium resembles that of a bird or turtle; the intermaxillary bones being very long, and curving downward, thus imparting to the fore-part of the head the profile of a parrot. There are no teeth apparent in

descriptions and figures, Geol. Trans. 2 ser. vol. vi.; *Odontography*, p. 195; and *Cyclop. Anat.*, Art. *Teeth*.

* "As in the existing diversified order of Batrachia, one family (*Perennibranchiata*) represents Fishes,—a second (*Ceciliadæ*), Serpents,—a third genus (*Pipa*), Chelonians,—and a fourth (*Salamandra*), Lizards,—so would the now lost Labyrinthodonts have formed Batrachian representatives of the highest order of Reptiles, viz. the Crocodilians."—*Prof. Owen, in Brit. Assoc. Rep.* 1841, p. 197.

† The relative proportions of all these great reptilian monsters can be easily studied in the Crystal Palace Gardens, where Mr. Waterhouse Hawkins has so boldly, truly, and artistically wrought into tangible shape the ideas of the comparative anatomist.

‡ Report on British Fossils, Rep. for 1841, p. 155.

either jaw, and Professor Owen supposes that this reptile may have had its jaws encased by a bony or horny sheath, as in turtles. Footmarks of a small reptile, with the print of a hind-toe pointed backwards, occur on the surface of some of the slabs of sandstone in these quarries, and are, with much probability, conjectured to have been impressed by the Rhynchosaurus.*

13. DICYNODON.—Although the geological position of the strata whence the specimens were obtained is somewhat uncertain, yet the relation between the reptiles whose remains I am about to describe and that last mentioned induces me to notice them in this place. The fossils in question were collected by Mr. Bain, in hard limestone-nodules occurring in a sandstone, supposed to belong to the Triassic system, in South Africa,† and were sent, with many other specimens of undescribed reptiles, to the Geological Society.‡ The principal remains hitherto cleared from the rock belong to reptiles having a flat cranium, with nostrils divided as in lizards, and not confluent as in turtles, which otherwise the skull in its general appearance much resembles. The orbits are very large; the jaws are edentulous, as in the Rhynchosaurus above described, with the exception that the upper jaw possesses a pair of long tusks § implanted in sockets, like those of the *Walrus*. The vertebræ, as in most of the extinct saurians, are sub-biconcave. This marvellous type of reptilian structure is perfectly unique.

* Cambridge Philosophical Transact., vol. vii. p. 355; Medals, p. 713.

† See Mr. Bain's Memoirs on the Geology of this region, and Prof. Owen's detailed descriptions of the several species of Dicynodon, in the 7th vol. of the Geol. Transact. 2nd series, 1845-57; and in the Descript. Catal. Foss. Rept. and Pisces, Roy. Coll. Surgeons, 1854, p. 80. See also *Medals*, vol. ii. p. 714, &c.

‡ This collection has been deposited in the British Museum; and several of the specimens have been perfectly cleared by Mr. Dew, and others will be exposed before long.

§ Hence the name *Dicynodon*, "two canine teeth."

The *Acrosaurus* is another extraordinary fossil reptile from the same locality. It has thirty or forty teeth on the alveolar ridge; and a broad process of the malar bone extending downwards over the side of the lower jaw, as in the Glyptodon (see p. 171). Prof. Owen has described specimens of the vertebræ of three other genera of great fossil Lacertia from the same peculiar South African formation. These are the *Massospondylus*, *Pachyspondylus*, and *Leptospondylus*; collected by Dr. Orpen, in the Drakenberg Mountains.*

14. Ichnolites, or Fossil Footsteps. — Some years since, the attention of geologists was excited by the discovery of impressions of the footsteps of quadrupeds on the surface of the red sandstone† at Corncockle Muir, in Dumfriesshire.‡ The imprints resemble those made by the paws or pats of land-tortoises. Entire tracks of these imprints, indicating the slow progression of a four-footed animal, appear on some of the slabs. On one block of sandstone there were twenty-four consecutive impressions of feet, forming a regular track, with six distinct repetitions of the marks of each foot, the fore-feet differing from the hind-feet; the appearance of five claws was discernible in each fore-paw. The

* Descript. Catal. Coll. Surg. 1854, p. 97.

† The red sandstone of Corncockle Muir was formerly referred to the New Red Series; but the researches of Mr. Binney and Prof. Harkness have shown that the several patches of red sandstones in the South of Scotland, excepting that of Annan, are of Permian age. Quart. Journ. Geol. Soc. vol. xii. pp. 138, and 254.

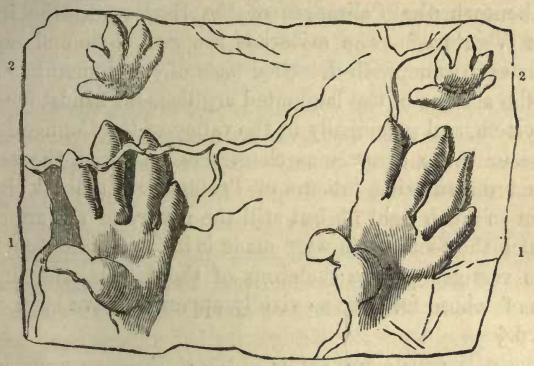
‡ Account of the Marks of Footsteps of Animals found impressed on Sandstone; by the Rev. H. Duncan, D.D., Edinburgh, Trans. Royal Soc. vol. xi. 1828. Numerous fossil foot-tracks from the quarries at Corncockle Muir are beautifully illustrated, of natural size and colours, in Sir W. Jardine's magnificent "Ichnology of Annandale;" and Prof. Harkness has described others in the "Annals of Nat. Hist." for 1851. In Mr. Morris's "Catalogue of British Fossils," 1854, p. 355, is a very perfect Synopsis of all the fossil foot-prints hitherto found in the British strata: but "Permian" must be substituted for "Trias" in the case of the Corncockle and Dumfries specimens.

observations already offered on the ripple-marks on sandstone (see p. 382) render it unnecessary to explain the preservation of imprints of this nature. Similar appearances have since been observed on the Triassic sandstone near Stourton and Runcorn in Cheshire, and in several places in Germany, but no bones of tortoises have been discovered in these strata.

A discovery of a like nature was made soon afterwards in the New Red sandstone near Hildburghausen, in Saxony. Numerous imprints of the feet of some large quadrupeds, having the fore-paws much smaller than the hinder, were observed on the exposed surfaces of some slabs of rippled sandstone: and similar footsteps have been found in the quarries at Stourton, Taporley, and Lymm in Cheshire, at Annan in South Scotland, and near Warwick. These imprints are on the face of each successive layer of stone; and on some of the slabs not only are there foot-prints of various kinds of animals that walked over the stone when it was in the state of soft sand, but also the impressions of rain-drops. Some of the recently exposed surfaces present a blistered or warty appearance, being covered either with little hemispherical eminences, or with depressions; and these, upon an accurate investigation of the phenomena, prove to have been the effect of rain, which fell while the surface was soft and impressible. On many of the slabs the forms of the rain-drops and of the foot-prints appear in relief, being casts of the surface upon which the impressions were made; while on the clay corresponding hollows are apparent (as in *Lign.* 133).

Chirotherium.—The foot-prints found on the sandstones and shales above referred to are of various kinds; some appear to have been produced by small reptiles and crustaceans; but the principal markings are referable to some large quadruped, in which the fore-feet were much smaller than the hinder (*Lign.* 132). From the supposed resem-

blance of these imprints to the shape of the human hand, the name of *Chirotherium* was adopted to designate the animals which left these enigmatical "footsteps on the sands of Time." Since the discovery of the bones of gigantic Sauro-



LIGN. 132.—NATURAL CASTS OF THE FOOT-MARKS OF THE LABYRINTHODON (CHIROTHERIUM) AND CASTS OF SUN-CRACKS, ON SANDSTONE; FROM HILDBURGHAUSEN.

Fig. 1, 1, Impressions of the hinder feet. 2, 2, Imprints of the fore feet.
(One-eighth the natural size.)
[*The imprints in this example are not right and left, but are parts of two tracks.*]

batrachians in the same strata, it has been suggested that the footmarks were produced by some of the large Labyrinthodons; a conjecture highly probable, for the fore and hind feet of many of the frog-tribe are as dissimilar in size as those of the so-called Chirotherium.*

15. ORNITHOIDICHNITES, OR FOSSIL FOOTPRINTS RESEMBLING THOSE OF BIRDS. — In the United States of North America, a group of strata, which, as far as the imperfect

* See Dr. Buckland's "Bridgewater Treatises" for figures and further details. A fine series of specimens of Chirotherian imprints are in the Brit. Mus. Collect. *Petrifactions*, p. 63. See also Geol. Transact. 2 ser. vol. vi. p. 537, and Geol. Soc. Journ. vol. ix. p. 37.

evidence afforded by their fossils can show, appear to belong to the Triassic system, occur in the valley of the Connecticut river, stretching through the states of Connecticut and Massachusetts; and a band of similar deposits ranges from beneath the Palisadoes of the Hudson to the interior of Virginia.* The materials are red shale and argillaceous sandstone, with detached beds of conglomerate.† It is on the surface of the laminated argillaceous sandstones of this system, and principally in the valley of the Connecticut, that occur those mysterious characters on which the sagacity and unremitting labours of Professor Hitchcock have thrown so much light; ‡ but still the nature of the animals by which the foot-prints were made is involved in obscurity, for no vestiges of the skeletons of the bipeds, the lineaments of whose feet are so vividly apparent, have been discovered.§

The origin assigned to these markings was for a long while disputed, but Professor Hitchcock's interpretation is now generally admitted;

* When the fossils of these Virginian sandstones, shales, and coal-beds are taken in consideration, the peculiar group of strata above alluded to must be regarded as having much of the character of the Lower Jurassic series of the North British area. See above p. 519.

† Professor Henry Rogers' Address at the Meeting of the Association of American Geologists, May, 1844.

‡ The reader is referred to Professor Hitchcock's "Report on the Geology of Massachusetts," to Dr. Buckland's "Bridgewater Treatise," to the "American Journal of Science," Transact. Americ. Phil. Soc. new ser., and Trans. Amer. Acad. Arts and Sciences, for many interesting papers by Dr. Deane (who first drew Professor Hitchcock's attention to the subject) and other American naturalists; and to the "Medals of Creation," p. 768; and "Petrifactions," p. 64.

§ Reptilian remains occur in the Red Sandstones of North America, (namely, the Clepsysaurus, Centemodon, and Bathygnathus, Geol. Soc. Journ. vol. xii. p. 377). Dr. Emmons has described the bone of a bird from the Chatham coal-field, in Carolina, probably of nearly the same age; and numerous relics of reptiles (Dictyosaurus, Omosaurus and Rutiodon or Clepsysaurus, and Compsosaurus or Palæosaurus), and some small Mammalian jaws from beds of Permian (?) age. Americ. Geol. part vi. 1857.

though the discovery of bones of birds in strata of this epoch is required before the question can be regarded as determined. The number and variety of these footsteps are so considerable, that in 1853 Professor Hitchcock considered he had sufficient data to warrant their arrangement in numerous genera, comprising upwards of fifty species, varying in size from half an inch to twenty inches in length; the greater part being referable to bipeds; whilst about a dozen quadrupeds can be recognised, most of them with the hind-feet much larger than the fore-feet.* The abundance of foot-prints on the Connecticut sandstones is explained by supposing the strata to have originated from sediments deposited in a tidal estuary; and that various kinds of birds and reptiles frequented the low muddy shores, when the tide receded, in pursuit of worms and other prey; and that their footsteps were covered with a thin layer of silt at each reflux of the waves.

The following remarks of Dr. Deane will convey an idea of the colossal proportions of some of these imprints:—"I have in my possession consecutive impressions of a tridactylous foot which measures eighteen inches in length, by fourteen in breadth, between the extremities of the lateral toes . . . . . Each step will hold half a gallon of water, and the stride is four feet." The original bird must have been "four or five times larger than the African Ostrich, and, on this basis, could not have weighed less than 600 pounds . . . . . Every step the creature took sank deep into the stratum, and the sub-strata bent beneath the enormous load. If an ox walk over stiffened clay, he would not sink so deeply as did this mighty bird." †

Sir C. Lyell mentions having seen on the banks of the Connecticut river (at Smith's Ferry, near Northampton, eleven miles from Springfield) "a space several yards square where the entire surface of the shale was irregular and jagged, owing to the number of footsteps, not one of which could be traced distinctly, as when a flock of sheep have passed over a muddy road; but, on withdrawing from this area, the confusion gradually ceased, and the tracks became more and more distinct." ‡

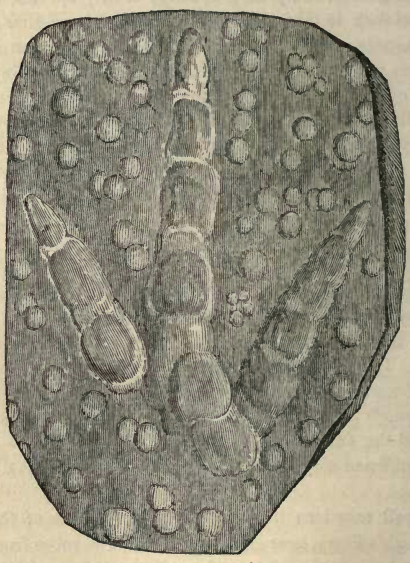
Some fine slabs of the sandstone, covered with several tracks of bipeds of various sizes, collected by Dr. Deane, are deposited in the British Museum. A representation of

* See "Final Report on the Geology of Massachusetts," p. 477; "Elementary Geology," p. 155; and "Geology of the Globe," p. 98.

† Boston Journal of Nat. Hist. vol. v. p. 282.

‡ Travels in North America, vol. i. p. 254.

one of the small imprints of the natural size, with the surface of the stone marked with hemispherical pits produced by a shower of rain, is given in *Lign.* 133.



LIGN. 133.—FOOT-MARK OF A BIPED, AND IMPRESSIONS OF RAIN-DROPS; on Sandstone; Massachusetts (*nat. size*).
[*American Journ. Science*, vol. xlvi. p. 73.]

The enormous magnitude of some of the foot-prints was formerly deemed an insuperable objection to the interpretation of these obscure vestiges adopted by the American naturalists; but the discovery of the bones of tridactyle birds (*Moa*, see p. 129) in the alluvial deposits of New Zealand, some of which indicate a size equal to that of the most colossal of the fossil imprints, has removed that objection, and shown that in comparatively modern times, the

earth was trodden by birds as gigantic as the bipeds that strode along the shores of the Triassic waters.

I must not, however, dwell longer on this inviting subject, and will only add, that, while offering my humble tribute of admiration to the sagacity and patience with which the subject has been investigated by Professor Hitchcock and others, and fully admitting the close resemblance of the bipedal fossil foot-prints to those of birds, I consider the following caution of Professor Owen to be deserving of the most serious attention: — "Foot-prints alone, like those termed 'Ornithichnites,' are insufficient to support the inference of the possession of the highly developed organization of a bird of flight by the creatures which have left them. The Rhynchosaur and biped Pterodactyles already warn us how closely the ornithic type may be approached without the essential characters of the Saurian being lost. By the Chirotherian Ichnolites we learn how closely an animal, in all probability a Batrachian, may resemble a pedimanous mammal in the form of its foot-prints." †

16. TRIASSIC MAMMAL.—Before leaving the subject of the Trias, we must again allude to the "Bone-bed," ‡ so closely related to the Lias in England, but decidedly Triassic in character on the Continent. At Stuttgard, among other very interesting fossils, it has yielded to the researches of Dr. Plieninger two minute *mammalian* teeth (*Microlestes antiquus*). These have been described and figured in the "Nova Acta," § 1850, and in Sir C. Lyell's "Manual."

* The close resemblance of many of these North American foot-marks to those made by recent birds is most striking. Sir C. Lyell, in his "Travels in North America" (vol. ii. p. 168, pl. 7), has placed this correspondence, I might almost say identity, in a strong point of view, by giving figures of recent foot-marks of the Sandpiper on hardened red mud, from the Bay of Fundy; these specimens are now in the British Museum and the Geological Society's Collection, for comparison with the fossil imprints.

† Brit. Assoc. Rep. 1841, p. 203. ‡ See above, p. 524.

§ Nov. Act. Cæs. Acad. Nat. Cur. vol. xxii. p. 902, pl. 71, fig. 14 and 15.

Taken in connection with the little fossil Mammals from Stonesfield and Purbeck,* and with Dr. Emmons's specimens from North Carolina (which last are probably more ancient than the *Microlestes*), these afford evidence of the existence of a marsupial fauna during the secondary epoch.

17. THE PERMIAN FORMATION.—The group of strata thus designated was formerly termed the Lower New Red, or Magnesian-limestone formation. It comprises the Bunter-Schiefer, Zechstein, Kupfer-Schiefer, and Rothliegendes of the Germans; that is, all the deposits intervening between the Carboniferous and the Triassic systems. Like the Trias, it consists of a triple series of deposits, namely, 1. Conglomerates, sands, and clays; 2. Limestones; 3. Sands and clays. The clays, sandstones, and conglomerates are more or less coloured by oxides of iron, and are associated with pyritous shales, gypsum, salt, &c.; some of the limestones, containing a large proportion of magnesia, are known as *Dolomite*,† and others, retaining a strong animal odour, are termed *Stinkstein*. This system being palæontologically characterized by a peculiar type of organic remains, and by the absence of nearly every species that occurs in the newer or overlying formations, the Permian is ranked as the last, or uppermost, of the palæozoic system. (See Synopsis, p. 203.) ‡

* See above, p. 394 and p. 508.

† The crystalline calcareo-magnesian rock (termed *Dolomite*, from M. Dolomieu, who first pointed out its mineralogical character) has the same external aspect as granular limestone; but, instead of being a pure carbonate of lime, contains from 45 to 60 per cent. of carbonate of magnesia.

‡ M. Pictet has shown, in the 4th volume of his new edition of "Paléontologie," pp. 577 and 579, that the proportion of *generic* forms passing from the earlier periods to the Permian is 56 per cent.; whilst of those received by the Trias from older periods the proportion is only 33 per cent. He considers that the palæontological difference of the Carboniferous period and the Permian may be approximatively indicated by "53," whilst "60" may indicate that between the Permian and Trias.

In the central part of England, and extending from the neighbourhood of Nottingham to the south-eastern extremity of Northumberland, red marls, sandstones, and breccias form the lowermost Permian strata, and are regarded as the equivalents of the *Rothliegendes* of Germany; a term applied to a group of red sandstones and conglomerates, accompanied with porphyry and other old volcanic rocks, that constitutes the base of the Permian series of the Continent. Upon these lower red sandstones are magnesian limestones, upwards of 300 feet in total thickness, corresponding with the *Stinkstein*, *Rauchwacke*, and *Zechstein* of Germany.

In the North of England the Permian formation is well developed, having four or more distinct members, and attaining about 1000 feet of thickness.* In the Midland Counties, the calcareous element is almost absent in the series, sandstones predominating, and, with the associated marls, making a thickness of upwards of 1500 feet.† Still further south and west the formation rapidly attenuates, and is represented by thin bands of sandstone and conglomerate, or breccia.

In Somersetshire, and the adjacent country around Bristol, beds of conglomerate,‡ formed of the debris of older rocks, held together by a

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* Mr. Binney has described the Permian beds of the North-West of England (Mem. Lit. Phil. Soc. Manchester, vols. xii. and xiv.) as consisting of, 1. (at top) Red and variegated gypsiferous marls (300 ft. thick); 2. Magnesian limestone (10 ft.); 3. Conglomerate (350 ft.); 4. Red sandstones and marls (500 ft.). Below these is the red and variegated sandstone of Whitstable, which Mr. Binney is disinclined to regard as Permian.

In the "Annals Nat. Hist." 2 ser. vol. xix. p. 33, &c., Mr. R. Howse describes the Permian series in Durham as consisting of, 1. (at top) Reddish sandstone (Lower Bunter?); 2. Upper yellow limestone (100 ft. thick); 3. Botryoidal limestone (150 ft.); 4. Cellular limestone and shell-limestone (150 ft.); 5. Compact limestone and conglomerate (200 ft.); 6. Marl-slate (3 feet). These are underlaid by sand and red sandstone, which, containing fish-remains and plants of species proper to the Coal-measures, are referred by Mr. Howse to the Carboniferous series, though hitherto regarded as the equivalent of the Roth-liegendes.

† See Mr. Jukes's description of the structure of the South Staffordshire Coal-field, in the "Records of the School of Mines," vol. i. p. 160; and Prof. Ramsay's Notice of the Permian rocks near Bridgenorth, Quart. Geol. Journ. vol. xi. p. 188.

‡ Mem. Geol. Surv. vol. i. p. 239. See Mr. Sanders's observations on the possibly Triassic age of this conglomerate, Brit. Assoc. 1849, Sect. p. 65.

dolomitic cement, are spread unconformably over the carboniferous strata, filling up the irregularities and hollows of the surface of the mountain-limestone, &c., occasioned by the dislocations and fractures which those rocks had sustained by disturbing forces, before the deposition of the Permian deposits. This conglomerate is made up in great part of pebbles and fragments of mountain-limestone, millstone-grit, coal-shale, and other detritus of the strata on which it reposes; and contains fractured and water-worn bones of Saurians, teeth of fishes, &c. It is well displayed, overlying the coal-strata and mountain-limestone, near Clifton in the valley of the Avon, and at Portishead, and other places in the vicinity.*

In Devonshire is a peculiar conglomerate or breccia, referred by Sedgwich and De la Beche to the Permian formation, and the structural characters of which point to the probable fact of eruptions of lava having been locally discharged into the Permian sea, and to have cemented together the water-worn materials, so as to form a *trap-conglomerate;*—such, at least, seems to have been the origin of the amygdaloidal trap, as it is termed, in the vicinity of Exeter.† A few miles to the south of that city, masses of a rock of this kind are interposed between beds of sandstone; the general appearance of the stone is that of a granular rock, somewhat loosely compacted, of a purplish-brown colour, interspersed with minute portions of calcareous spar, mica, and indurated clay tinged by copper or manganese. It is full of small ovoidal cells, which are either filled or lined with manganese, calc-spar, or jasper; a structure termed in geology *amygdaloidal*, or almond-like: the substance of the rock is an earthy felspar.

Another interesting feature of the Permian series is a breccia, or conglomerate of pebbles and angular stones imbedded in a red marly matrix,‡ belonging to the lower portion of the series, and occurring over a large extent of country in Worcestershire and South Staffordshire. It consists of more or less worn fragments of quartz, slates, traps, sandstones, and fossiliferous rocks, many of which are traceable, in Prof. Ramsay's opinion, to parent-rocks in the Welsh border-country, sometimes 50

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* The dolomitic conglomerates near Bristol and on the Mendip Hills are ably described by Buckland and Conybeare, Geol. Trans. 2nd ser. vol. i. p. 291.

† Geology of England and Wales, p. 294; Geol. Proceed. vol. ii. p. 196; De la Beche's Report, Devon, &c., p. 203.

‡ Phillips, Mem. Geol. Survey, vol. ii. part i. p. 112; Ramsay, Quart. Geol. Journ. vol. xi. p. 155, and Notices, Roy. Instit. April 24th, 1857.

miles distant. From this circumstance, and on account of the size, angularity, smoothness, and striated appearance of many of the stones, Prof. Ramsay considers that they could have been transported and brought together only by the agency of floating ice; just as the boulders of the Pleistocene drift * are acknowledged to have been borne from great distances and accumulated by means of icebergs and coast-ice.

18. Magnesian Limestone or Dolomite.—The magnesian limestone of England is regularly stratified, and, when recently exposed, has a granular or saccharine structure, with a glimmering lustre; the colour is generally either a pale-fawn, salmon, or yellow, from hydrate of iron,—or red, from oxide of iron. The hard varieties yield some of the best building-stone in England.†

In many places the limestone occurs in large concretional and botryoidal masses; the concretions varying from the size of small peas to that of large cannon-balls; and these are often grouped together like bunches of grapes, or masses of chain-shot. On the coast of Durham, the whole cliff is made up of large concretional clusters, resembling piles of cannon-balls. This phenomenon is best seen near Sunderland, and along the shore near Marsden and Black Rocks; where it is associated with other curious and interesting modifications of concretional action.‡ These masses offer a beautiful illustration of spheroidal structure, superinduced on stratified detritus *after its deposition;* for the sedimentary laminæ pass through the globular concretions uninterruptedly. The limestone is commonly traversed by veins and strings of carbonate of lime, and occasionally contains hollow spheroids of calcareous spar and crystals of sulphate of strontian and barytes. Galena, or sulphide of lead, sulphide of zinc, calamine, and carbonate of copper, also occur; and some veins of galena in the Mendip Hills have yielded profitable returns.§

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* See vol. i. p. 217, &c.

† The New Houses of Parliament at Westminster are constructed externally of magnesian limestone, from quarries at North Anstone in Yorkshire, and near Worksop in Nottinghamshire.

‡ See an admirable Memoir, "On the Geographical Relations and internal structure of the Magnesian Limestone," by the Rev. Adam Sedgwick, Geol. Trans. 2nd Ser. vol. iii. p. 37

§ Geology of England and Wales, p. 304.

19. PERMIAN OF GERMANY AND RUSSIA. — In Thuringia* and Saxony the magnesian limestone (*Stinkstein*, *Rauchwacke*, and *Zechstein*) is largely developed, and is underlaid by a thin band of dark bituminous shales highly charged with copper-pyrites, which is termed the *Kupfer-Schiefer*. These shales have long excited the attention of naturalists from the number and variety of the fossil fishes they contain, and the peculiar mineralized condition in which these relics occur; specimens from Eisleben near Mansfeld,† a celebrated productive locality of these ichthyolites, are to be found in almost every museum in Europe. These fishes, which principally belong to the genera *Palæoniscus*, *Pygopterus*, and *Platysomus*, are generally in a contorted state, apparently the effect of violent convulsions attendant on their sudden destruction. The appearance of a violent death presented by these Ichthyolites is regarded by M. Agassiz as entirely deceptive: and he states that the bent and twisted condition of the body is solely attributable to muscular contractions during decomposition after life was extinct.‡ The specimens are splendidly invested with copper-pyrites, and their scales often have the appearance of burnished gold. The bodies of the vertebræ of the spinal column are almost always wanting.§

The researches of Sir R. Murchison and his colleagues ‖ have shown that the Permian system in European Russia

* The elaborate memoir, by Sir R. Murchison and Prof. Morris, on the Palæozoic rocks of the Thuringerwald and the Harz, comprises a clear exposition of the relations of the Permian rocks of these districts. Quart. Journ. Geol. Soc. vol. xi. 420, &c.

† An account of this locality, and a geological Map of the district west of Halle, are given by M. Paul Herter in the Transact. Nat. Hist. Soc. of Halle, vol. iv.

‡ Recherches sur les Poissons Fossiles, tome ii. p. 70.

§ Medals, p. 601.

‖ Russia in Europe and the Ural, chap. viii.

consists of strata similar to the great group of red and variegated marls, sandstones, conglomerates, and associated magnesian limestones, of England and Germany, and reposes on the Carboniferous deposits. It extends over an area 4,000 miles in circumference; a space equal to twice the surface of the kingdom of France.

The Permian deposits of Russia, which occupy so vast a region to the east of the river Volga, namely, in the governments of Kasan, Viatka, Perm, and Orenburg, are composed of calcareous flagstones, with gypsum, red and green grits and shells (with copper-ores and plant-remains); magnesian limestones and marlstones; conglomerates, red and green sandstones, &c. It is worthy of remark, that the plant-remains, the fossil reptiles, and the coppery beds are in Russia found frequently above the great bands of limestone, whilst in Germany, on the contrary, they occur below the limestones.

20. Fossils of the Permian System.—The fauna and flora of this formation are invested with peculiar interest, because they present us with the last term of the palæozoic creation, that ancient type of organic life which prevailed from the earliest periods, affording any evidence of the presence of living things in the waters or upon the surface of our planet. For the two grand changes in the organic world, as demonstrated by fossil remains, are unquestionably those which separated the palæozoic ages from the secondary, and the latter from the tertiary. There are no less than 166 species of fossil plants and animals from the Permian deposits which have been accurately determined; of these 148 are unknown in any other formation.

Plants.—The plants are in great part referable to genera common in the coal-measures, but very rare or altogether wanting in the formations above the Permian; for example, species of *Lepidodendron*, *Nœggerathia*, *Odontopteris*, *Pecopteris*, *Sphenopteris*, and *Calamites*, indicating a continuation

of vegetable life of the same nature as that which prevailed during the Carboniferous era.

Near Chemnitz, in Saxony, silicified stems of tree-ferns (*Psaronites*) occur; numerous trunks of coniferous trees (*Araucarites*) are common in the Rothliegendes at Kyfhausen; and other plant-remains are met with near Zwickau and elsewhere in the same kingdom.* At Allesley,† near Coventry, silicified trunks of coniferous trees have been found in the Permian sandstone (formerly referred to the New Red); and other plant-remains, such as *Caulerpites*, *Breea*, *Lepidodendron*, and *Calamites*, are mentioned by Professor Ramsay‡ as having also occurred in these beds in Warwickshire.

21. INVERTEBRATA OF THE PERMIAN.—The *Radiaria*, *Mollusca*, and *Articulata* occurring fossil in the Permian rocks of England and Ireland have been described with much care by King,§ Howse,‖ and Kirkby,¶ who enumerate upwards of 130 species. Tragos, Dentalina, Spirillina, Calamopora, Spirorbis, Cythere, Prosoponiscus, Fenestella, Strophalosia, Monotis, Bakevillia, Schizodus, Turbo, Chemnitzia, Pleurotomaria, and Nautilus are the principal genera.**

22. FISHES OF THE PERMIAN.—The fishes of this system comprise beween forty and fifty species, belonging to sixteen or seventeen genera :†† most of these genera and a few of the species occur also in the Carboniferous series of rocks. All

* Gutbier's Verstein. Permisch. Syst. Sachsen; and Geinitz's Steinkohl.

† Geol. Proceed. vol. ii. p. 439.

‡ Quart. Geol. Journ. vol. ix. p. 198. Prof. King enumerates seven Permian plants in his Monograph, Pal. Soc. 1856.

§ Monograph, Palæontog. Society, 1850; and Ann. N. H. vol xvii.

‖ Annals Nat. Hist. 1857, vol. xiii. pp. 33, 304, and 463.

¶ Quart. Journ. Geol. Soc. vol. xiii. p. 213.

** A comparative table of the fossil animals of the Permian system, as far as known in 1845, is given in the "Geology of Russia," vol. i. p. 221. Schlotheim, Reuss, Schauroth, &c. have described the Permian fossils of Germany.

†† About seven of these genera occur in the Permian rocks of England.

the ichthyolites of this group possess that remarkable modification of the tail which we have already mentioned as having been of excessive rarity in the fishes of the secondary and tertiary seas, as well as in those that inhabit the existing ocean; in which the Sharks and Sturgeons are almost the only representatives of this palæozoic type. The caudal fin is universally heterocercal; that is, the vertebral column is prolonged at its extremity into the upper lobe of the tail.* One of the most striking ichthyological features of the Permian deposits is the prevalence of fishes of the genus *Palæoniscus*,† of which several species abound in the Permian and Carboniferous strata of England, Europe, and North America. These fishes belong to the heterocercal ganoids, and are covered with rhomboidal scales, which in some species are very small, and in others large. In one locality near Dungannon, in Ireland, a small species is sometimes found in groups of more than two hundred individuals on a slab of stone not exceeding two feet square. One species only of the genus (*Palæoniscus superstes*) has been identified in the Trias.

23. REPTILES OF THE PERMIAN.—The earliest certain indications of the existence of reptiles on our globe have been obtained from the deposits of the Carboniferous and Devonian formations; for neither teeth nor bones of animals of a higher order than fishes have been discovered in any of the more ancient formations.

The *Archegosauri* of Saarbruck, the *Dendrerpeton* and *Baphetes* of Nova Scotia, the *Parabatracus* of Carluke, and

* See figure of the restored figure of the *Amblypterus* (*fig.* 183, p. 770) of the Carboniferous system, in which *a* marks the prolongation of the vertebral column into the upper lobe of the caudal fin: this fish is a good illustration of the *heterocercal* type; and the *Lepidotus* of the Wealden (*Lign.* 105, p. 423) affords an example of the *homocercal* fish.

† Professor Sedgwick's memoir, *Geol. Trans.* 2 ser. vol. iii. is accompanied by numerous figures of Palæonisci (pl. 8 and 9). See also Agassiz, Poiss. Foss. vol. ii., and King's Monogr. Perm. Foss. 1850.

some lately discovered reptilian footprints in the coal-shale of Deane Forest, well represent the reptilian forms of the Carboniferous period, when evidently there were many cold-blooded quadrupeds coeval with the luxuriant flora of the coal.* The little *Telerpeton Elginense* † and some probably chelonian footprints remain as evidences of the Devonian reptiles—the oldest yet known; and in Pennsylvania reptilian foot-tracks occur both on the Carboniferous and the Devonian rock-surfaces.‡

In some of the Permian rocks reptilian remains are not unusual; and indeed they form important characteristics of these deposits. The bituminous Kupferschiefer of Thuringia has yielded the *Protosaurus* (the "fossil monitor of Thuringia," for a long time the oldest-known reptile); the copper-bearing Permian conglomerates of Russia are sometimes rich with bones of reptiles; in the dolomitic conglomerate of Somersetshire the remains of large thecodont § lizards have been found; and similar forms occur, according to Dr. Emmons,‖ in the Permian strata of the Chatham coal-field in North Carolina.

Thecodontosaurus and *Palæosaurus*.—These British fossils were obtained from Redland, near Bristol, and are preserved in the museum of that city; they consist of jaws, teeth, vertebræ, and bones of the extremities, referable to two genera of saurians, named as above by Dr. Riley and Mr. Stuchbury, by whom they were first made known.¶ The teeth are pointed, compressed laterally, trenchant, and finely serrated on the edges. These reptiles, in their thecodont type of dentition,

* Medals, vol. ii. p. 748. † Medals, vol. ii. p. 720.

‡ American Journ. Science, new ser. vol. i. p. 268, and vol. ii. p. 25; and Medals, vol. ii. p. 749.

§ *Thecodont;* i. e. having the teeth implanted in distinct sockets, as in the crocodile.

‖ American Geology, part 6, 1856, p. 85.

¶ Geological Transactions, 2nd ser. vol. v. p. 359, pl. 29 and 30.

biconcave vertebræ, double-headed ribs, and proportionate size of the bones of the extremities, are nearly related to the Teleosaurus of the Oolite (p. 532); but combine a lacertian form of tooth and structure of the pectoral arch with these crocodilian characters: and the bodies of the vertebræ have a series of ventricose excavations for the spinal chord, instead of a cylindrical canal. The reptile found in the copper-shales, and termed the "Thuringian fossil monitor" (*Protorosaurus*), appears to be related to the thecodont saurians of Bristol. The spinous processes of the dorsal vertebræ are described as remarkably high, and the caudal vertebræ are characterized by double diverging spinous processes.

Rhopalodon.—Fragments of jaws with teeth, and a few detached teeth, of thecodont reptiles, apparently related to the Bristol saurians, are amongst the reptilian remains obtained from the Permian deposits of Russia. They are figured and described by M. Fischer under the generic name of Rhopalodon.*

From what has been advanced respecting the fossils hitherto found in the Permian formation, it appears that the organic remains are distinct from those of the contiguous upper system or Trias, and present a close relation to the types which characterize the lower deposits.

24. REPTILES.—As the multitude of reptilian forms with which we have been surrounded in our progress through the faunas of the secondary epochs disappears with the Triassic epoch, and as the reptiles of the Palæozoic system are comparatively limited in number, I will here offer a few general observations on this class of animals, that the unscientific inquirer may be enabled to comprehend the inferences that arise from the facts submitted to his notice.†

* Sur le Rhopalodon, genre de Saurien Fossile du versant occidental de l'Oural; par G. Fischer de Waldheim, Moscou, 1841, and Bullet. Soc. Nat. Moscou, 1845.

† See "Medals of Creation," vol. ii. chap. xvii., for a fuller consider-

All animals possess organs by which a certain change is effected in the circulating fluid, to refit it for the purposes of nutrition. Mammals, birds, and reptiles are furnished with an apparatus of areolar and vascular tissue, termed lungs, by which a large surface of the blood is brought in contact with the air; in aquatic vertebrates (fishes) this apparatus is the gills, which are organs fringed with innumerable processes, supplied by myriads of vessels, disposed like net-work, by which the blood is exposed to the action of aerated water, oxygen absorbed, and vitality maintained. In Reptiles, the respiratory organs are less developed than in any of the other vertebrated animals, but they all possess lungs, and are capable of breathing air: and some have gills, and perform aquatic respiration. The heart, which is generally three-chambered, is so disposed, that at each contraction only a portion of the volume of blood is sent to the lungs; hence the action of oxygen on the circulating fluid is in a less degree than in any of the mammals, birds, or fishes. As animal heat, the susceptibility of the muscles to nervous influence, and even the nature of the skin, are dependent on respiration, the temperature of Reptiles is low, and their muscular powers are, on the whole, very inferior to those of Birds or Mammals: requiring no integuments, as hair, wool, or feathers, to preserve their temperature, they are merely covered with scales, or have a naked skin. As they can suspend respiration without arresting the course of the blood, they dive with facility, and remain under water for a long period without inconvenience. Some are viviparous, others are oviparous, laying their eggs, which they

ation of the subject. For a comprehensive and philosophical view of this department of Palæontology, the English reader should study the memoirs of Prof. Owen in the British Association Reports, 1839, 1840, and 1841; and his Monographs published by the Palæontographical Society. Pictet's 'Paléontologie,' also, should be consulted, both for the details of the fossil reptiles, and for references to other authors.

never hatch, on the sands or banks. They present great diversity of form; some are extremely elegant, others grotesque and hideous, and many have dermal processes of the most fantastic shapes. Their habits are exceedingly variable; some are agile, others torpid; all hibernate, or rather relapse periodically into a state of dormancy, whether produced by cold, drought, or excessive moisture. Their peculiar structure enables them to endure long abstinence, to an extent impossible to other races of animals. Their seasonal habits, or, in other words, alternate periods of activity and repose, are in accordance with the sudden evolutions of the seasons; they are dormant when nature does not need their agency, and rouse into activity when required to repress the redundancy of those vegetables or animals which constitute their food; a property strikingly manifest in the species of hot climates; thus exhibiting an admirable adaptation to the peculiar conditions of existence which they are destined to fulfil. Some are herbivorous, others carnivorous, and many prey on insects; their powers of progression are as various; some orders, though destitute of fins, wings, or feet, bound along the ground with great agility (the Serpents); others walk or swim; while a few are capable of flight.*

25. TURTLES, OR CHELONIAN REPTILES.—In Turtles the want of active faculties is compensated by their passive means of resistance. They have no weapons of offence, but are enclosed in a panoply of armour formed by the expansion of the costal plates above, and by the ossified plastron beneath.† The carapace, or buckler, constituting the shell that spreads over the back of the turtle, is composed of bony plates continuous with the ribs, which, instead of being separated by intervals, as in other animals, are united together by the

* The *Draco volans*, or Flying Dragon.

† See Owen, "On the Carapace and Plastron of Chelonian Reptiles," Phil. Transact., 1849, p. 151.

costal plates. Thus in the delicate and agile form of the Serpent, and in the heavy and torpid mass of the Turtle, the same general principle of structure prevails, and, by a simple modification, the skeleton is adapted for beings of very dissimilar forms and habits. The *Testudinata*, or turtles, like the other large reptiles, are essentially confined to torrid and temperate regions. The fresh-water species are capable of bearing a higher latitude than the terrestrial: upon the whole the utmost range of this order appears to be from 54° N. lat. to about 40° S. lat.* The fluviatile species, or *Emydes*, are carnivorous, feeding on frogs and small animals; those of the genus *Trionyx* (*three-claw*) are African or Asiatic, with the exception of the *Trionyx ferox*, which inhabits the hot regions of America. They live upon food which is found at the bottoms of rivers; in the stomachs of several procured from the Ganges, by Col. Sykes, were large quantities of mussels, the shells of which were broken into small angular fragments. The fossil bones of a Trionyx-like animal (*Tretosternon Bakewelli*) from Tilgate Forest, were imbedded in a mass of mussel-shells; a collocation which might be expected in a fluviatile deposit. The form of the ribs and other parts of the skeleton differs in the Chelonians of the land, marshes, rivers, and the sea respectively, so that the fossil bones can, for the most part, be readily referred to the respective groups.

Fossil Tortoises and Turtles.†—The earliest indications of the existence of reptiles on the surface of our planet are supposed to be those of Chelonians; the imprints of the feet or pats apparently of a land-tortoise occurring on a slab of Devonian sandstone in Morayshire;‡ and similar footprints have been found in the millstone-grit of Cheshire,§ and are

* "The Testudinata," by Thomas Bell, 1 vol. folio; one of the most splendid works on Natural History that has appeared in this country.

† Medals, vol. ii. p. 726. ‡ Quart. Geol. Journ., vol. viii. p. 97.

§ Ibid. vol. xii. p. 350.

of more frequent occurrence in the Permian sandstone of Dumfriesshire,* and the Triassic beds at Stourton and Runcorn, in Cheshire. Throughout the Oolitic, Wealden, and Cretaceous epochs, Chelonians abounded; and from the most ancient Tertiary to the present time the four groups of this order of reptiles have flourished. Their remains, in great plenty and of prodigious size, are associated with those of the Sivatherium, &c., in the Sub-Himalayas; and with those of Mastodons in the Burmese empire, of Palæotheres in the French, Swiss,† and Isle of Wight tertiaries, and with fruits of tropical plants in the Isle of Sheppey; their bones and eggs are daily imbedded in the recent coral-sand of the Isle of Ascension. The remains of living species of Indian land-tortoises are said to be collocated with the bones of extinct miocene mammalia in the Sewalik hills.‡

26. CROCODILES.—This family of loricated or mailed saurian reptiles contains the only living types that at all approach in magnitude the colossal forms of the secondary epochs. The Egyptian Alligator, as is well known, attains a large size; and the long and slender-beaked crocodilian reptile of India, the Gavial (or Garial) of the Ganges, sometimes reaches a length of nearly thirty feet. The peculiar character of the teeth of these animals, and their mode of increase and renovation, have already been pointed out (p. 429). The vertebræ, or bones of the back, are concavo-convex; *i. e.* united to each other by a ball-and-socket joint, the convexity being behind. Some of the fossil crocodiles of the tertiary also have this structure of the spinal column; but in every crocodilian of the secondary formations, the articulating surfaces of the vertebræ are either flat or concave, except in one genus (*Streptospondylus*§), in which the vertebræ are convexo-concave, *i. e.* the convexity is directed forwards: a position the reverse of the ordinary type. Reptiles of the crocodilian

* Jardine's Ichnology of Annandale. † Pictet and Humbert's Monog.
‡ Falconer and Cautley. § Medals, p. 680.

order, but belonging to several extinct genera, swarmed throughout the whole of the secondary and tertiary epochs. As the living crocodilians frequent fresh water, the remains of animals of this type indicate the existence of countries watered by streams and rivers, or abounding in lakes: but the modification of the spinal column, so prevalent in the ancient forms, may, perhaps, be referable to a marine rather than to a terrestrial condition of existence, in some of these extinct saurians.

27. ENALIOSAURIANS, or MARINE LIZARDS.*—*Ichthyosaurus* (*Fish-like Lizard*).—In the lias of the west of England, teeth, vertebræ, and other parts of the skeletons of reptiles, which were supposed to be related to the Crocodiles, had for many years excited attention; but until 1814, when a considerable collection, from Dorsetshire, formed by Mary Anning, was sold in London, no accurate investigation of these interesting relics had been attempted.† Subsequently a great number of skeletons have been found, numerous memoirs published, and the form and structure of the originals thoroughly investigated. Many beautiful specimens are figured and described in the splendid work of Mr. Hawkins, whose unrivalled collection of these remains is now deposited in the British Museum.‡ The bones of reptiles so abundant in the Lias are chiefly referable to two genera; the one called *Ichthyosaurus* (by Mr. König), to denote its relation to fishes and reptiles; the other, *Plesiosaurus* (so named

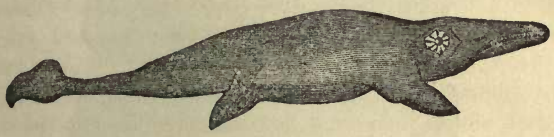
* Medals, p. 663.

† See No. I. of Charlesworth's "London Geological and Palæontological Journal," for an account of the sale of this collection.

‡ "Memoirs of Ichthyosaur and Plesiosaur;" by Thomas Hawkins, folio, with Plates, 1838; and "Book of the Great Sea-dragons," folio, with Plates, 1840. Fully to realize the external form and general character of the Ichthyosauri and Plesiosauri, the student must visit the Crystal Palace Gardens, and make himself acquainted with Mr. Waterhouse Hawkins's life-sized models of these extinct sea-reptiles; smaller models of which also are obtainable for study in the cabinet.

by Mr. Conybeare), to indicate that it approached nearer than the animals of the other genus to the Lizards, or Saurians.

The Ichthyosaurus had the beak of a porpoise, the teeth of a crocodile, the head and sternum of a lizard, the paddles of a cetacean, and the vertebræ of a fish. This restoration (*Lign.* 134) shows its general configuration, as demonstrable from the skeleton; from the peculiarity of the terminal vertebræ of the tail, Prof. Owen concludes that the original had a strong vertical tail-fin.* There are many species, some of which are of a magnitude equal to that of young whales. The teeth are conical, sharp, and striated, resembling those of crocodiles in the power of reproduction, but differing in the number, situation, and mode of regeneration: one species



LIGN. 134.—RESTORED FIGURE OF THE ICHTHYOSAURUS.

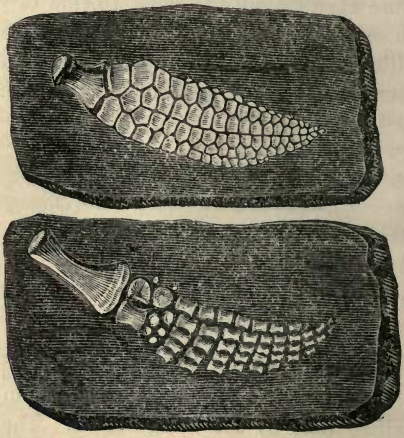
has 110 in the upper, and 100 in the lower jaw; they are arranged in a deep furrow or groove, not in sockets, and were retained only by the integuments. The orbit is very large, and the sclerotic or outer coat of the eye is made up of thin bony plates, arranged round the central opening or pupil, as in the owl and other birds; a mechanism by which the power of the eye is materially increased, and vision adapted to near or remote objects at will. The bones forming the sternum, or chest, which protect the organs of respiration, are strong, and largely developed,† and the sternal arch offers a remarkable correspondence with that of the Ornithorhyncus of Australia.

* Geol. Trans. 2nd ser. vol. v. p. 511.

† Medals, p. 667

Like turtles, the Ichthyosaurus had four paddles, composed of numerous bones enveloped in one fold of integument, so as to form an entire fin, as in the cetacea;* the fore-paddles are large, and in some species consist in one hundred bones (*Lign.* 135); the hinder pats are smaller, and contain but thirty or forty. The internal structure of these instruments therefore resembles that of the paws of turtles: and (as is even the case in the fin of the Porpoise) the same elements

1.



2.

Lign 135.—Paddles of the Ichthyosaurus and Plesiosaurus, in Lias Shale, from Lyme Regis.

Fig. 1. Left fore-paddle of the Ichthyosaurus.
Fig. 2. Left fore-paddle of the Plesiosaurus.
(One-eighth the natural size.)

of an arm are found as in the quadrupedal mammalia, viz. a *humerus*, *radius*, *ulna*, and *phalanges*. The nostrils, which in

* The soft integuments of the paddle are occasionally preserved: see the figure of a beautiful example from Barrow-on-Soar, Geol. Trans. 2nd ser. vol. vi. pl. 20, and Medals, p. 669.

Crocodiles are situated at the extremity of the beak or muzzle, are in the Enaliosauri placed, as in the Cetacea, beneath the orbits. The vertebræ are somewhat hourglass-shaped, but less so than in the sharks and other fishes; the spinal column admitted of the utmost freedom of motion, while in the neck the vertebræ connecting the head to the spinal column are anchylosed, and have supplementary bones to increase the strength, and diminish motion.* The general figure of the Ichthyosaurus must have been that of a Grampus or Porpoise, with four large paddles. The teeth prove it to have been carnivorous; the paddles, that it was aquatic; the scales, bones, and other remains of marine fishes constantly found in the abdominal cavities of the skeletons, and in the coprolites,† that it was an inhabitant of the sea. Its skin appears to have been naked, or at least destitute of scales.‡

28. THE PLESIOSAURUS.§—The discovery of a remarkable specimen, by Miss Anning, enabled Mr. Coneybeare at once to establish the characters of that extraordinary extinct marine reptile, the Plesiosaurus, which differs from the Ichthyosaurus in the extreme smallness of the head, enormous length of the neck, and other osteological peculiar-

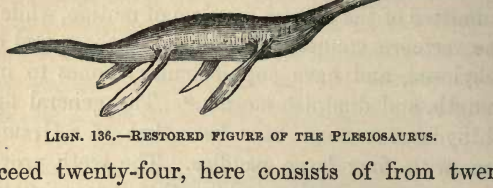
* Memoir on a Peculiarity of Structure in the Neck of the Ichthyosaurus, by Sir P. M. de Grey Egerton. Geol. Trans. 2nd ser. vol. v. p. 187.

† The *Coprolites*, or fossil excrements, of Ichthyosauri (the true nature of which was first ascertained by the sagacity of the late Dean of Westminster) are found in profusion in the clays and marlstones of the Lias; often occupying the abdominal cavity of the skeleton (see Dr. Buckland's Bridg. Treat., p. 190, pl. 15); and the state of preservation of these peculiar bodies is such, as to show not only the nature of the food of these reptiles, but also the dimensions, form, and structure of the stomach and intestinal canal. The coprolites of the fishes of the chalk often afford like indications. See above, p. 358; and Medals of Creation, p. 621.

‡ Relics of the skin occur in a fossil state. See Buckland's Bridgewater Treatise, Plate 10, fig. A. 1, 2, 3, 4; Mr. Cole's paper on the skin of the Ichthyosaurus, Geol. Journal, vol. ix. p. 79; and Mr. C. Moore's remarks on the subject, Report Brit. Assoc., 1856, p. 69.

§ Medals of Creation, p. 671.

ities.* The neck, which in most animals is composed of five vertebræ, and in the extreme recent example, the Swan, does



LIGN. 136.—RESTORED FIGURE OF THE PLESIOSAURUS.

not exceed twenty-four, here consists of from twenty to forty; and its length is sometimes equal to that of the entire body and tail. This reptile combines in its structure the head of a lizard, with teeth implanted in sockets like the crocodile, —a neck resembling the body of a serpent,—a trunk and tail of the proportions of those of a quadruped,—with paddles like the turtle (*Lign.* 135, *fig.* 2). The vertebræ are longer and less concave than in the Ichthyosaurus, and the ribs, being connected by transverse abdominal processes, present a close analogy to those of the Chameleon.

The collection of Mr. Hawkins, now in the British Museum, contains a skeleton eleven feet long, and so nearly perfect, that the entire form of the original creature may be completely restored. The late Dean Coneybeare compared the Plesiosaurus to a turtle stripped of its shell, and thought it probable, from its long neck presenting considerable impediment to rapid progress in the water, that it frequented the coast, and lurked among the weeds in shallow water. As it is evident that it must have required frequent respiration, it probably swam on or near the surface, and darted down upon the small fishes on which it preyed.

Ichthyosaurs and Plesiosaurs have been found throughout the secondary strata, from the Lias to the Chalk inclusive; with the exception of the Wealden, in which no traces of

* In the sternum of the Plesiosaurus the *coracoid* bones have their greatest development. Medals, p. 667, fig. 213.

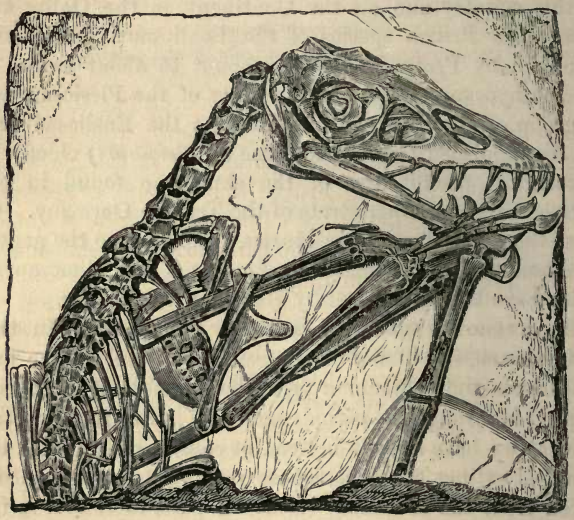
Ichthyosauri have been discovered. Lyme Regis is the most celebrated locality in England, but the remains of numerous species of both genera have been discovered in many places in this country and on the Continent, in the Oolite and Lias. The British species of the Enaliosauri known and described by Professor Owen, amount to about twelve of the Ichthyosaurus, and nearly twenty of the Plesiosaurus.* A group of Reptiles, nearly related to the Enaliosaurians, but distinguished (under the name of *Simosauri*) chiefly by osteological peculiarities of the skull, are found in the Muschelkalk and other strata of the Trias in Germany. Of these there are about eight species, belonging to the genera Nothosaurus, Pistosaurus, Conchiosaurus, and Simosaurus, which have been described by Hermann von Meyer.

29. Pterodactyles, or Flying Reptiles.†—In this rapid sketch, it will not be necessary to dwell on the first appearance and subsequent great development of the Lacertian tribes through the periods embraced in this retrospective view, as we have already noticed at considerable length the principal extinct Saurians, whose remains have been disinterred from the secondary rocks. I pass, therefore, to the Pterosaurians, or Flying-lizards, of the ancient world, which unquestionably present the most extraordinary modification of reptilian organization which the researches of the palæontologist have brought to light. With a head and length of neck resembling those of a bird, the wings of a bat, and the body and tail of an ordinary mammal, these creatures present an anomaly of structure as unlike their fossil contemporaries as is the duck-billed Platypus or Ornithorhyncus of Australia to existing animals. The skull is small, with a long beak, furnished sometimes with upwards of sixty sharp-pointed teeth; the size of the orbit denotes a

* British Assoc. Reports for 1839, p. 126; and Monog. Cret. Rept. 1851

† Pterodactylus, *i. e. Wing-finger.*—See Medals of Creation, p. 723.

large eye, and it is therefore probable that the smaller species, like other Insectivora, were nocturnal. The outer or



LIGN. 137.—SKELETON OF A FLYING REPTILE: FROM SOLENHOFEN.

(Pterodactylus crassirostris. Goldfuss. One-third the natural size.)

From the Nova Acta Acad. Carol. Leop., vol. xv. pl. viii.

little finger is immensely elongated for the support of a membraneous expansion, similar to that which is extended on the fingers of the Bat; impressions of this membrane are seen in some specimens (*Lign.* 137). The fingers terminate in long hooks, like the curved claw of the Bat. The size and form of the foot, leg, and thigh show that the Pterodactyles were capable of perching on trees, and of standing firmly on the ground, where, with their wings folded, they might walk or hop like a bird.*

* See Dr. Buckland's Bridgewater Treatise. Mr. Martin has intro-

Twenty species of these extraordinary creatures have been discovered, varying in size from that of a Snipe to that of a Cormorant or an Albatross. Of these, twelve have been found in the lithographic stone of Bavaria,* where the bones of Pterodactyles are associated with the remains of Dragon-flies; in the Stonesfield Slate they are collocated with the *elytra*, or wing-cases, of beetles. In the Lias, the remains of a species of the size of a Raven were discovered by Miss Anning.† This species and three of those from Bavaria do not belong to the Pterodactyle proper; but, having no teeth, and being distinguished by their long stiff tail, they are separated by Von Meyer, under the name of *Ramphorhyncus* (Beak-nose).

Numerous thin delicate bones, evidently belonging to Pterodactyles, have been found in the Wealden, and prove that some species of these extraordinary creatures inhabited the country of the Iguanodon. In the Chalk of Kent, the upper and lower jaw-bones with teeth, portions of a coracoid bone, several digital bones, and parts of the arm-bones of large Pterodactyles, have been obtained. From a comparison of these relics with the specimen of *P. crassirostris* (*Lign.* 137), the Kentish species appear to have been much larger, and it is estimated that the expanded wings of *P. Cuvieri* would be, at least, eighteen feet wide; whilst in another Chalk species the extent of the wings from tip to tip was fifteen feet.‡ Among existing reptiles, the diminutive *Draco volans* is the only known species capable of flight.

duced a restored figure of a Pterodactyle in the foreground of the Frontispiece of Vol. I. of this work.

* Goldfuss, Nova Acta Acad. Nat. Cur. vol. xv. p. 63. This memoir, by the great German palæontologist, is illustrated by excellent figures of Pterodactyles from Solenhofen. See also Münster's "Beiträge."

† Geological Transactions, 2nd Ser., vol. iii. page 220. This unique specimen is now in the British Museum.

‡ The majority of the rare and valuable specimens from the Chalk, by

30. Ophidians (*Serpents*) and Batrachians (*Frog-tribe*).—There are no vestiges in the secondary formations of the Ophidians, or reptiles destitute of feet or any extremities for progressive motion; but in the tertiary, bones of a few species of large serpents, chiefly allied to the Boas and Pythons, have been discovered. These fossils were obtained from the Eocene sand, at Kyson, in Suffolk, from the London Clay of the Isle of Sheppey, and the Bracklesham beds on the Hampshire coast.* From the size of the vertebræ, Professor Owen ascertained that some of these Eocene serpents must have exceeded twenty feet in length. "Serpents of such dimensions," he observes, "exist in the present day only in warm or tropical regions; and their food is by no means restricted to animals of the cold-blooded classes. . . . Living birds or quadrupeds constitute the favourite food of the Pythons and Boas, of similar dimensions, which are exhibited in our menageries."†

A large fossil serpent, having some alliances with the Rattle-snake and other venomous Ophidians, has lately been described (under the name of *Laophis crotaloides*) by Prof. Owen,‡ from evidences afforded by several vertebræ collected near Thessalonica by Captain Spratt. It is probably of the Miocene age.

Batrachians.—The reptiles termed Batrachians (from the Greek name for Frog) are characterized by the remarkable metamorphoses which they undergo in the progress of their development from youth to maturity. Their organs of aerial respiration consist of a pair of lungs; but in their young and

means of which these gigantic Pterodactyles have been determined, enrich Mr. J. S. Bowerbank's choice collection at Highbury. See Owen's Monograph of the Chalk Reptiles, Palæont. Soc., 1851.

* Medals of Creation, p. 738.

† Geol. Trans. 2nd ser. vol. vi. p. 210.

‡ Geol. Journ. vol. xiii. p. 196, pl. 4.

aquatic state they are provided with gills, supported on cartilaginous arches, as in fishes. The early existence of colossal reptiles closely allied to this order has already been shown in the Labyrinthodons of the Triassic system (see p. 552). In the tertiary strata, the skeletons, imprints of the footsteps, and even vestiges of the soft parts of several species of Frog, Toad, and Newt, have been found.* In the *papierkohle* of the Browncoal of the Rhine (see p. 283), several species are met with.† In the neighbourhood of Bombay, small batracholites have been found in a black shale, apparently of tertiary date.‡

But the most celebrated fossil of this class, from the tertiary deposits, is a gigantic Salamander, three feet in length, obtained more than a century since, from the miocene lacustrine limestone of Œningen, in the same quarry which yielded the fossil Fox previously described (see p. 268). The first discovered specimen of this fossil Batrachian (*Lign.* 138) acquired great celebrity, from an eminent physician of his day, Scheuchzer, having, under some extraordinary delusion, regarded it as a petrified human skeleton, and described it, under the name of "*Homo Diluvii Testis et Theoscopos*," as being "the moiety, or nearly so, of the skeleton of a man, with the bones and flesh incorporated in the stone, and a relic of that accursed race which was overwhelmed by the Deluge." §

Cuvier, when at Haarlem, in 1811, examined this specimen, and ascertained it to be the skeleton of an extinct species of aquatic Salamander; he cleared away the stone and exposed the four legs, and the jaws, beset with teeth.‖ There are

* See Pictet's Paléontologie, 2de edit. vol. i. p. 561.

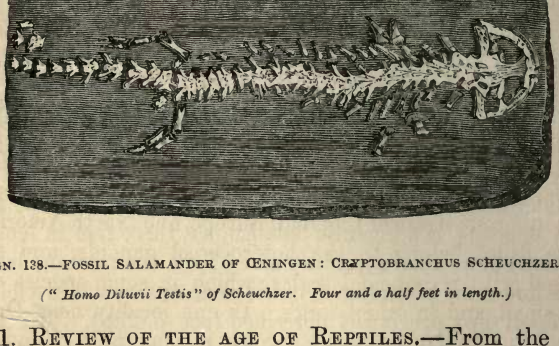
† Goldfuss, Nova Acta, vol. xv. part 1, p. 107, pl. 11, 12, and 13.

‡ Geol. Journal, vol. iii. p. 224.

§ Philos. Trans. for 1726, vol. xxxiv.

‖ A full account and illustrations of this fossil are given in the "Ossemens Fossiles," vol. v. p. 431

some fine remains of the Œningen Salamander in the collection of the British Museum.



LIGN. 138.—FOSSIL SALAMANDER OF ŒNINGEN: CRYPTOBRANCHUS SCHEUCHZERI.

("Homo Diluvii Testis" of Scheuchzer. Four and a half feet in length.)

31. REVIEW OF THE AGE OF REPTILES.—From the examination of the organic remains of the Secondary Formations we obtain the following results: that the seas, lakes, and rivers during these geological periods swarmed with reptiles, fishes, mollusca, crustacea, annelida, echinodermata, zoophytes, foraminifera, sponges, and sea-weeds; all of extinct species, and presenting, as a whole, a greater discrepancy with existing forms than those of the Tertiary; the most remarkable feature being the apparent absence of Cetacea (p. 325), and the presence of several genera of marine Reptiles.

On the land we find but little analogy to the terrestrial inhabitants belonging to the tertiary or present eras: throughout the vast accumulations of the spoils of the ancient Islands and Continents, although the remains of crocodiles, fresh-water turtles, insects, and terrestrial plants abound, a few jaws of very small animals are the sole indications of the existence of Mammalia; and the evidence of the presence of Birds is even less clear. In vain we seek for the relics of Man, or the remains of works of art,—for the skeletons

of the Mastodon or the Mammoth,—of the Palæotheres, or other mammals that were their contemporaries; the osseous remains of terrestrial and fluviatile Reptiles alone appear. In the emphatic language of Cuvier, "*Nous remontons donc à un autre âge du monde,—à cet âge où la terre n'étoit encore parcourue que par des reptiles à sang froid, où la mer abondoit en ammonites, en bélemnites, en térébratules, en encrinites, et où tous ces genres, aujourd'hui d'une rareté prodigieuse, faisoient le fond de sa population.*"*

The earliest indications of air-breathing vertebrate animals is the little Elgin reptile, and the supposed imprints of chelonian footsteps in Devonian sandstone. In the succeeding Carboniferous, Permian, and Triassic periods, Saurobatrachians occur, often of great bulk, and in great numbers; and on the later sands of those old shores are found the foot-tracks of bipeds which seem to point to a higher class, that of birds, for their origin. In the following periods, embracing the deposition of the Lias, Oolite, Wealden, and Chalk, swarms of reptiles belonging to numerous genera everywhere prevail; species fitted to live in the air, on the land, in lakes and rivers, and in the seas,—yet not one identical with any existing form. These gradually decline as we approach the close of the secondary, and are succeeded in the tertiary by as varied modifications of the higher animals—the mammalia and birds. Thus, the faunas of the vast periods that intervened between the tertiary and palæozoic ages present the following numerical relations in the three higher classes of the vertebrata:—

MAMMALIA . .	Seven † genera of small land-animals (p. 394, 508, and 561). Wirtemberg, Stonesfield, and Purbeck.

* "Ossemens Fossiles," tome v. 2de partie, p. 10.

† Mr. Beckles has specimens of other Purbeck genera, still undescribed. The *Dromatherium* (Emmons), being probably Permian, is not reckoned here.

BIRDS	A species from North Carolina (p. 558, *note*); another from Stonesfield? (p. 524); another from the Wealden? (p. 452); and many species inferred from footprints on sandstone of the Triassic period? (p. 557).
REPTILES . . .	*Marine;*—Fifty genera, including above one hundred and forty species. *Terrestrial* and *Fluviatile;* — Forty-five genera, comprising about two hundred species. *Flying;*—Two genera, containing nineteen species.

Here, then, the classes Mammalia and Aves, which constitute the essential features of the existing terrestrial faunas of almost all countries, are represented through a period of time of incalculable duration, by a few diminutive quadrupeds, by some uncertain vestiges of birds, and problematical foot-prints of bipeds on the rocks; while everywhere bones, teeth, and entire skeletons of reptilian forms, adapted for aerial, terrestrial, and aquatic existence, afford unequivocal proofs that the air, the land, and the waters were tenanted by cold-blooded vertebrate animals. In the succeeding tertiary ages, the fossil remains of reptiles belong to species of existing types, and are associated with the relics of innumerable mammiferous quadrupeds.

Now, if we admit, to the utmost extent, the effect of causes that may be supposed to have operated to the exclusion of the remains of mammalia from the secondary formations, still the overwhelming preponderance of the reptilian tribes, both on the land and in the waters, is most striking. And here we may inquire whether this remarkable phenomenon warrants the hypothesis which some eminent geologists have advanced, namely, that during the periods antecedent to the eocene, the earth was not adapted for the existence of mammalia?—that it was in a state of turbulence and convulsion, which colossal reptile forms were alone calculated to endure; that it was a half-finished planet, unsuitable for warm-blooded animals; and that its atmosphere was

incapable of supporting the higher types of animal organization? The probability that birds existed in the country of the Iguanodon—the certainty that marsupial and insectivorous mammals were the contemporaries of the Megalosaurus and Pterodactyles—that trees and plants, similar to many which now grow in regions abounding in birds and warm-blooded quadrupeds, flourished throughout the "Age of Reptiles," are facts which appear to me fatal to such a hypothesis, and to prove that the general temperature of the earth, and the physical constitution of the sea, and the atmosphere, were not essentially different from those which now prevail. That the class of reptiles was developed, throughout the periods embraced in this review, to an extent far beyond what has since taken place, cannot, I conceive, by any legitimate process of reasoning be disputed; but I do not think that in the present state of our knowledge any satisfactory explanation of this extraordinary fact can be offered.

32. OBJECTIONS CONSIDERED.—There are persons who, with one of the Bridgewater essayists (Mr. Kirby*), oppose these conclusions, and have recourse to the most strange conceits to account for the phenomena on which they are founded. But it is for those who refuse their assent to deductions made with the greatest caution, and derived from an overwhelming mass of evidence, to explain the entire absence of all traces, not only of Man, but of the whole existing species of animals and vegetables, in the ancient deposits; while there is not a river or stream which does not daily imbed the remains of the present inhabitants of the globe. But, however future discoveries may modify this hypothesis, they cannot invalidate the fact, that there is no country on the face of the earth with such an assemblage of animal life as that possessed by the regions whence the delta of the Wealden was derived; nowhere is there an island or a con-

* Seventh Bridgewater Treatise.

tinent inhabited by colossal reptiles only, or (excepting the Galapagos) where the Reptilia usurp the place of the large Mammalia. We have seen that this feature in the zoology of that remote period was not confined to the country of the Iguanodon; in every part of the world where geological researches have extended, this wonderful phenomenon appears —the absence of mammiferous animals in the older strata. The bones of reptiles, sometimes of enormous size, are there the only remains of the higher animals (except fishes) that occur in any considerable number. It is, therefore, manifest, that there was a period when oviparous quadrupeds of appalling magnitude were the chief possessors of the lands of which any traces remain in the strata that are accessible to human observation. I do not, however, mean to aver, that reptiles, and reptiles only, were the occupiers of every Island and Continent; but that it appears from the most irrefragable testimony, that the reptile tribes during the secondary periods were developed to an extent of which the present state of animated nature affords no example. It must be acknowledged that the proposition is astounding, and I do not feel any surprise that many intelligent persons, whose attention has not previously been directed to geological inquiries, should hesitate to admit its correctness; but the conclusion is drawn from such an immense accumulation of facts, corroborated by observations made in every region of the earth, as to compel assent, in spite of all our preconceived opinions. We may, indeed, call up from the depths of our ignorance hypotheses as marvellous as the phenomena they are intended to explain, but which a very slight examination of the facts before us would prove to be untenable.

33. CONCLUDING REMARKS.—There is another objection to which I would allude; for I do not think with some, that the errors or prejudices of those who differ from us should be treated with silence or contempt; but, rather, that it is

our duty to explain, again and again, the foundation of our belief, in the hope and assurance that we shall at length remove the erroneous opinions of persons whose scepticism arises from their imperfect acquaintance with the subject. It has been insisted upon by those whose views are limited to the present state of the globe, that the supposition of the earth having been peopled by other creatures before the existence of the human race is incompatible with the evident design of the Creator, and derogatory from the dignity of Man, for whose pleasure and necessities they assume all living things were created. But this inference is at variance with what we know of the living world around us: everywhere we see forms of animated existence utterly unconscious of the presence of Man, and endowed with faculties and sensations wholly dissimilar from our own. Thus, while in the beautiful language of Scripture we are told that not a sparrow falls to the ground without our heavenly Father's notice, a philosophical examination of the present constitution of nature would alike condemn such vanity and presumption. For my own part, feeling, as I do, the most profound reverence and the deepest gratitude to the Eternal Being, who has given unto me this reasoning intellect, however feeble it may be,—and believing that the gratification and delight experienced in the contemplation of the Wonders of Creation here are but a foretaste of that inexpressible felicity which, in a higher state of existence, will be our portion hereafter, I cannot but think that the minutest living atom, which the aided eye of man is able to explore, is designed for its own peculiar sphere of enjoyment, and is alike the object of His mercy and His care, as the most stupendous and exalted of His creatures.

"Le même Dieu créa la mousse et l' Univers."

In nothing, perhaps, are we more mistaken than in our estimate of the happiness enjoyed by other beings; to em-

ploy the beautiful simile of a distinguished author,—"As the moon plays upon the waves, and seems to our eyes to favour with a peculiar beam one long track amidst the waters, leaving the rest in comparative obscurity, yet all the while she is no niggard in her lustre; for, although the rays that meet not our eyes seem to us as though they were not, yet she, with an equal and unfavouring loveliness, mirrors herself on every wave; even so, perhaps, happiness falls with the same power and brightness over the whole expanse of being, although to our limited perceptions it seems only to rest on those billows from which the rays are reflected back upon our sight." * And if we admit, as all must admit who for one moment consider the marvels which Astronomy has unfolded to us, that there are countless worlds around us, inhabited by intelligences of whose nature we can form no just conception, surely the discoveries of Geology ought not to be rejected because they instruct us, that ere man was called into existence this planet was the object of the Almighty's care, and teeming with life and happiness.

Thus Geology reveals the sublime truth, that through periods of incalculable duration, our globe was the abode of myriads of living creatures, enjoying all the blessings of existence, and which at the same time were the destined instruments for the elaboration of the materials, by which the surface of the earth was rendered, in the course of innumerable ages, a fit temporary abode for intellectual and immortal beings! †

* Sir E. B. Lytton's "Eugene Aram."

† See M'Cosh and Dickie's "Typical Forms and Special Ends in Creation," 1856, for some interesting remarks on the adaptations of both fossil and recent animals and plants to their functions and conditions, and a brief notice of the evidences of a long preparation for the advent of man upon the earth (p. 345).

LECTURE VI.

ON ZOOPHYTA AND CRINOIDEA.

1. Introductory. 2. Organic and Inorganic Bodies. 3. Distinction between Animals and Vegetables. 4. Nervous System and Sensation. 5. Diversity of Animal Forms. 6. Zoophytes. 7. Animal nature of Zoophytes. 8. Cilia, or vibratile organs. 9. Hydræ, or Fresh-water Polypes. 10. Elementary organic structure. 11. Analogy not Identity. 12. The Bryozoa. 13. Food of Zoophytes. 14. Nature of Zoophytes. 15. Corals or Polypifera. 16. Sertularian Zoophytes. 17. Actinoidea or Corallaria. 18. Caryophyllia and Turbinolia. 19. Madrepore. 20. Fungia. 21. Astræa, Pavonia, &c. 22. Mæandrina cerebriformis. 23. Alcyonarian Zoophytes: Gorgonia. 24. The Red Coral. 25. Tubipora. 26. Geographical Distribution of Corals. 27. Appearance of living Corals. 28. Coral Reefs. 29. Coral Reef of Loo-Choo. 30. Coral Islands. 31. Formation of Coral Islands. 32. Montgomery on Coral Islands. 33. Fossil Zoophytes. 34. Ventriculites. 35. Zoophytes of the Oolite and Lias. 36. Corals of the Palæozoic Formations. 37. Coralline Marbles. 38. The Crinoidea. 39. Structure of the Crinoidea. 40. Encrinites and Pentacrinites. 41. Derbyshire Encrinital Marble. 42. The Lily-Encrinite. 43. Pear-Encrinite of Bradford. 44. Pentacrinites and Actinocrinites. 45. Pentremites and Cystidea. 46. Concluding Remarks.

1. Introductory.—In many of the deposits of the Secondary formations reviewed in the last discourse, a large proportion of the fossils were seen to consist of those interesting types of animal organization, the Polypifera and Crinoidea: some of the Oolitic strata, as for example the *Coral-rag*, being wholly made up of Corals; while many of the limestones and shales of the Lias equally abound in Pentacrinites and other forms of the Crinoidea. In the more ancient palæozoic formations, to the examination of which our attention will hereafter be directed, we shall find these organisms in still greater profusion: entire mountain-chains consisting of the consolidated remains of corals, and vast tracts of limestones composed of the mineralized skeletons of the Lily-shaped animals.

To enable the unscientific reader to comprehend the ori-

gin and formation of these ancient fossiliferous rocks, I therefore purpose devoting the present Lecture to a general view of the natural history of some of the recent animals of these classes, and a brief notice of the most characteristic fossil species.

2. ORGANIC AND INORGANIC BODIES. — The beautiful world in which we are placed is everywhere full of objects presenting innumerable varieties of form and structure, of action and position; some of them being inanimate or inorganic, and others possessing organization or vitality. The organic kingdom of nature, in like manner, is separated into two grand divisions, the animal and the vegetable. The differences between organic and inorganic bodies are numerous and manifest; but it will suffice for my present purpose to mention a few obvious and familiar characters.

All the parts of an inorganic body enjoy an independent existence; if I break off a crystal from this mass of calcareous spar, the specimen does not lose any of its properties, it is still a group of crystals as before: but if a branch be separated from a tree, or a limb from an animal, each is rendered imperfect, and the parts removed suffer decomposition,—the branch withers, and the limb undergoes putrefaction. If crystals, which may be considered the most perfect models of inorganic substances, be formed, they will remain unchanged, unless acted upon by some external force of a chemical or mechanical nature: within, every particle is at rest, nor do they possess the power to alter, increase, or diminish: they can enlarge by external additions only, and decrease but by the removal of portions of their mass.*

* These remarks must be taken in a general sense only, since various experiments have demonstrated that the molecules of inorganic matter undergo modification by the slightest action of light and variation of temperature.

"Prismatic crystals of zinc are changed in a few seconds into octahedrons by the heat of the sun. We are led from the mobility of fluids to expect great changes in the relative positions of their molecules, which must be in perpetual motion even in the stillest water or calmest air; but we were not prepared to find motion to such an extent in the interior of solids. We knew that their particles were brought nearer by cold or

But organic bodies have characters of a totally different nature; they possess definite forms and structures, which are capable of resisting for a time the ordinary laws by which the changes of inorganic matter are regulated, while internally they are in constant mutation. From the first moment of the existence of the plant or animal to its dissolution there is no repose; youth follows infancy,—maturity precedes age; it is thus with the moss and the oak,—the monad and the elephant,—life and death are common to them all.

Animals and vegetables also require a supply of food and air, and a suitable temperature, for the continuance of their existence; and they are nourished by fluids elaborated by appropriate organs, and transmitted through suitable vessels. In the germ of an animal or a vegetable there is a vital principle in action, by which are developed in succession the ordained phenomena of its existence. By this power the germ is able to attract towards it particles of inanimate matter, and bestow on them an arrangement widely different from that which the laws of chemistry or mechanics could produce. The same power not only attracts these particles, and preserves them in their new situations, but is continually engaged in removing those which might by their presence prevent or derange its operations; and, on the other hand, so soon as the vital principle deserts the body which it has animated, the latter immediately becomes subjected to the agencies which act on inorganic matter: "in obedience to the power of gravitation the pliant twig hangs down, and the slender stem bends. In animals the body falls to the ground; the pressure of the upper parts flattens those on which the others rest; the skin stretches out; and the graceful rotundity of life is exchanged for the oblateness of death." * The laws of chemistry then begin to operate,—

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pressure, or removed farther from one another by heat; but it could not have been anticipated that their relative positions could be so entirely changed as to alter their mode of aggregation. It follows from the low temperature at which these changes are effected, that there is probably no portion of inorganic matter that is not in a state of relative motion. Prismatic crystals of sulphate of nickel exposed to the summer heat, in a close vessel, had their internal structure completely altered, so that when broken open they were composed internally of octahedrons, with square bases. The original aggregation of the internal particles had been dissolved, and a disposition given to arrange themselves in a crystalline form."—*Mrs. Somerville, On the Connexion of the Sciences*, p. 171.

* Dr. Fleming; Philosophy of Zoology, vol. i. p. 39.

putrefaction takes place,—and, finally, dust returns to dust, and the spirit of Man to Him who gave it.

3. DISTINCTION BETWEEN ANIMALS AND VEGETABLES.—I have thus briefly described a few of the phenomena peculiar to organic existence; it will now be necessary to offer some remarks on the distinguishing characters of animals and vegetables; for, unless we have a clear perception of the phenomena peculiar to each, we shall not obtain correct ideas of the nature of zoophytal organization.

When we compare together those animals and vegetables which are considered as occupying the highest stations in each kingdom, we perceive that they differ from each other in particulars so obvious and striking, as not to admit of question. The horse and the grass upon which it feeds—the bird and the tree in which it builds its nest—are so essentially distinct from each other, that we perceive at once that they belong to distinct classes of organic nature. But it is far otherwise when we descend to those animals and plants which occupy the lowest stations in vitality: here the functions to be performed are but few, the points of difference obscure, and it requires a correct knowledge of the laws of organization to enable us to determine, with any degree of precision, where animal life terminates, and vegetable existence begins. The Lichen which grows on the stone, and the Zoophyte attached to the rock, present but little difference to the common observer; both are permanently fixed to the spot on which they grow, from the earliest period of their existence to their dissolution; and in the vegetable dried by the heat of the sun, and the polype shrivelled up from the absence of moisture during the ebb of the tide, he would seek in vain for those characters which would assign the one to the vegetable, and the other to the animal kingdom.

4. NERVOUS SYSTEM AND SENSATION.—My limits will

not permit me to dwell on the distinctions which exist between animals and vegetables in their chemical composition, nor on the different influence produced on the atmosphere by their respective agency: and I must content myself with explaining the remarkable endowment which is supposed to be peculiar to animal organization, namely, that of *sensation*, and to be dependent on that structure which is termed the Nervous or medullary system.

When any object comes in contact with my finger, I am sensible of its presence, and the finger is said to possess sensation: but if I compress or cut across the nerve which passes from the spinal marrow to the arm, this faculty of sensation is suspended or destroyed: the same object may come in contact with my finger as before, but no feeling is excited indicating to me its presence. This phenomenon is well known, for every one must sometimes, in lying or sitting, have compressed the nerve of the arm or thigh, and occasioned a temporary numbness and loss of accurate feeling in the limb. I perceive, then, by my own experience, that sensation is inseparably connected with the presence and condition of the nerves; and that in Man and the vertebrated animals the nervous influence is developed and transmitted by means of the brain, spinal chord, and nerves.

In examining the other divisions of the animal kingdom, the presence of a nervous system, more or less developed according to their respective intellectual and physical endowments, may be detected. In those of the higher orders, nervous filaments can be distinctly traced, from their origin in the brain or spinal marrow, to their distribution in the various parts to which they communicate sensation, and to the organs to which they impart the influence necessary for the performance of their several functions. But in proportion as the systems of absorbing, secreting, and circulating vessels become less, a corresponding diminution takes place in the nervous fibres, until at length both vessels and nerves elude our finite observation, and we are left to infer from analogy, that probably since sensation depends upon the presence of nerves, and the smallest animals evidently possess sensation, a nervous system exists in the minutest Monad which the highest power of the microscope enables us to descry.*

* Hence Rudolph, the celebrated physiologist, terms those animals in which no traces of *nervine*, or nervous matter, can be detected, the *Cryptoneura*, or hidden-nerved.

Our knowledge of the nervous system, even in the higher animals, is

In the largest and most complicated vegetable organisms no traces of nerves are perceptible, nor of any substance which can be considered as at all analogous in structure or function: it is therefore concluded, that, as vegetables are destitute of nerves, they are likewise wanting in the faculty we term sensation.*

But the nerves not only bestow feeling, they also confer the power of voluntary motion; and, if the organs to which the motor nerves proceed be suitably constructed, they enable the animal to effect progression, or, in other words, to change its situation from one place to another. As we descend in the scale of creation, we find many animals destitute of that power, and living on the same spot from the commencement to the termination of their existence; and all these creatures are inhabitants of the water.

Such, then, are the essential characters of animals—an external determinate form, gradually developed, with an in-

still imperfect; and "that there may be sensibility without nerves, and contractility without muscles," in the lower animals is a statement that has some support from observation. See "Seaside Studies," Blackwood's Magazine, 1857, p. 413, &c.

* Although the definition here given is sufficient for our present purpose, yet it is necessary to state, that, in a more rigorous and philosophical view of the subject, a line of demarcation between the vital phenomena exhibited by animal and vegetable organisms cannot be established. The possession of a stomach or digestive sac, and the power of locomotion, formerly thought to be peculiar to animals, are no longer regarded as such. Even the difference in the chemical processes effected by plants and animals,—namely, the absorption of carbonic acid and the evolution of oxygen by the former, and the opposite effects produced by the latter —though a very general, is not a constant character; for some animals evolve oxygen; and from all the parts of plants which are not green, carbonic acid is exhaled: and when light is removed from the plant, the same thing happens everywhere. See *Dr. Bence Jones's Gulstonian Lectures*, for 1846. The very difficult subject of the distinctive separation of the border-forms of animal and vegetable life is treated more or less fully in nearly every work, original or compiled, on zoology and physiology: for example, see Literary Gazette, 1856, p. 965; and Brit. and For. Med. Chir. Review, July, 1856, p. 3. The reader should also avail himself of the lucid and eloquent résumé of opinions on this subject in M. P. H. Gosse's elegant little work on "Life in its Lower, Intermediate, and Higher Forms," 1857, p. 25, &c., where Dr. Burnett (in Siebold's "Comparative Anatomy") is especially quoted.

ternal organization possessing vessels for effecting nutrition and support, and capable of attracting and assimilating particles of inorganic matter; combined with a nervous system communicating sensation and voluntary motion; a certain term of existence being assigned to determinate forms,—in other words, a period of life and death.

5. DIVERSITY OF ANIMAL FORMS.—Animals are as varied in form and magnitude as the imagination can conceive; from the god-like image of Man to the globule of jelly that floats upon the wave,—from the Elephant and the Whale to the Insect and the Animalcule, of which millions may be contained in a drop of water. In fact, so numerous and dissimilar, both in form and structure, are the animal organisms that exist on the earth, that the opinion of Astronomers that the inhabitants of the worlds around us must, from the different densities and conditions of the respective planets, be totally distinct and unlike any that are known to us, cannot be considered as incredible or marvellous.* But of all the shapes in which animal existence presents itself on our globe, none are more extraordinary, or unlike what is commonly conceived of living beings, than those of the compound creatures which have been described by naturalists under the name of "Zoophytes," or "Animal-plants," and are familiarly known in their varied forms by the names of Polyps, Corals, Dead-men's-hands, Sea-pens, Sea-fans, Sponges, &c.

6. ZOOPHYTES.—In classifying the Animal Kingdom, naturalists have always readily recognised the distinctness of the three great divisions, now known as the Vertebrated (*Vertebrata* of Cuvier), the Molluscous (*Mollusca* of Cuvier), and the Articulate or Annulose animals (*Articulata* of Cuvier; *Annulosa* of Macleay); but besides these there is an extensive and somewhat heterogeneous series of ani-

* See Thoughts on Animalcules, or a Glimpse of the Invisible World revealed by the Microscope, p. 7.

mals, generally of far more simple structure as individuals, though frequently existing in compound and intimately united groups. These were termed *Radiaria* or *Radiata* by Lamarck, Fleming, and others, on account of the apparent or fancied radiation of the organs and parts of the animal. In this sub-kingdom were arranged the Echinoderms, the Zoophytes, the Entozoa, the Infusoria, the Sponges, &c. Recent researches have led to an improved classification of these lower animals in many respects, as may be seen in the works of modern anatomical and physiological naturalists;* and it will be sufficient here to point out that the word *Zoophyte* is now technically used to indicate the Corals only, although in a general sense all the plant-like animals are sometimes called Zoophytes.

Of these plant-like animals there are three important and very distinct groups. The *Bryozoa*,† or "Moss-animals;"

* See Owen's Lectures on the Invertebrate Animals, 2nd Edit.; Carpenter's General and Comparative Physiology, New Edit.; Huxley's Lectures on General Natural History in the "Medical Times," 1856—57; Van der Hœven's Hand-book of Zoology (translated by Dr. Clarke); Siebold's Hand-book of Invertebrate Animals; Milne Edwards' Zoologie; Dallas's Natural History of the Animal Kingdom; Rymer Jones's Animal Kingdom, New Edit.; Agassiz and Gould's Comparative Anatomy, &c., New Edit. (Bohn.)

† So called by Ehrenberg, on account of their small branches and frond-like forms, in contrast with the *Anthozoa*, or "Flower-animals," as he terms the true Corals, with the finely coloured flower-like expansions on their branching and often tree-like skeletons. Both of these groups have also other names; for instance, the *Bryozoa* or Moss-corals are the "Polyzoa" of Thompson, the "Zoophyta Ascidioida" of Johnston, and the "Ciliobrachiata" of Farre; and the Corals are the "Polypifera" of Grant, and the "Phytozoa" of Brandt.

The name *Bryozoa* is here preferred to the somewhat earlier one of "Polyzoa" (which Dr. Busk uses in his valuable descriptions of these little animals, in his "Catalogue of the Marine Polyzoa in the British Museum," and in his "Zoophytology" in the "Microscopical Journal"), because it is a better and more distinctive name, there being several other groups of *Polyzoic* animals; because it has been extensively used in

the *Anthozoa*, or Corals (*Zoophyta* proper); and the *Amorphozoa*, or Sponges.

The Bryozoa* are compound animals, grouped on a horny or calcareous frame-work (termed the "polyzoary," or the "polypary," as is also that of the Corals, also the *cœnœcium*, or "common dwelling"); the individuals or polypes are of minute size; the body has a ring of hollow ciliated tentacles around the mouth; the alimentary canal consists of a stomach, gizzard, and an intestine, which has a free separate vent,—a character of much importance, placing the Bryozoa above the Corals in the scale of creation, and indicating their alliance, on the one hand, to the *Rotifera* among the Articulata, and to the *Brachiopoda* and *Tunicata* among the Molluscs, on the other. Many of the Moss-corals occur on the shells, rocks, and seaweeds of our shores; and some of them take the form of delicate Algæ, and have been often collected as such. They have been also miscalled "Corallines;" but the real Corallines (*Corallina officinalis* and its allies), although stony in structure, are really plants, belonging to the Algæ: there is, therefore, no relation, except that of "mimetic resemblance," between the Corallines and the Corals, much less the Bryozoa.

The *Anthozoa*, or *Polypifera*,† comprise three kinds of

zoology and palæontology; and because, in the case of appellations invented for groups of animals, plants, or minerals, whether they be names of genera, families, orders, or classes, it is not the priority, but the adaptability of the term that should, with few exceptions, determine the general use of such appellations, under which the many series of described species are successively grouped and regrouped by philosophical naturalists.

With "specific" names, however, the case is different; the published name of a species is (or ought to be) not only the established technical appellation of a distinct form in nature, but also the registered evidence of the successful labour and acumen of its discoverer and describer.

* Medals of Creation, vol. i. p. 265, &c.

† Medals, vol. i. p. 251, &c. See also Edwards and Haime's Mono-

Polyp-animals,—1st, one of very simple form of structure, like that of the "Fresh-water Polype," or *Hydra;* hence this group is called the *Hydroida*:* 2nd, with a less simple structure, other cavities existing in the body, besides that of the stomach; this is typified by the common Sea-anemone (*Actinia*); and the group is termed the *Actinoidea* or *Zoantharia* (animal-flowers), including the great mass of the stony Corals (Madrepores, &c.): and, 3rd, the *Asteroida* or *Alcyonaria*, having the common *Alcyonium* or Dead-man's-hand for their type, and being characterized by their nearly simple stomach, and by the polypary being either spongy or horny and gelatinous, and rarely forming a stony axis.

The Sponges, or *Porifera*,† present innumerable variations of form; they are composed of a usually fibrous skeleton, covered with a gelatinous coating, in which cilia and temporary alimentary openings have been observed;‡ the skeleton or axis is perforated with large and small passages, and is frequently interwoven with silicious or calcareous spicula. These creatures are much lower in the scale than either of the other Zoophytes. They hold a place on the confines of animality, and indeed present but few essential points of difference from vegetable organisms.

A group of fossil bodies, chiefly from the chalk, and known under the name of "Ventriculites,"§ were long regarded as Sponges; but, on account of certain peculiarities in the structure of their tissue, Mr. Toulmin Smith‖ has assigned to them a higher place in the animal series.

graphs on Fossil Corals (Introduction), 1850—54, Palæont. Society; Dana's Zoophytes; Blainville's Actinologie, &c.

* Also known as the *Sertularidæ*. † Medals, vol. i. p. 219.

‡ Bowerbank, Report Brit. Assoc., 1856 and 1857; and Roy. Soc. Proc. 1857.

§ See above, vol. i. p. 330; and Medals, vol. i. p. 241. In the Linnæan Transact. vol. xi. p. 401, the author first referred these peculiar organic bodies to the *Alcyonium*.

‖ Annals Nat. Hist. 2 ser. vol. i. 1848, p. 36, &c.

7. ANIMAL NATURE OF ZOOPHYTES.—Corals were long regarded by Naturalists as animal-plants (as the word "Zoophytes" literally means), but Ferrante Imperato, in 1599, and Peysonnel,* in 1751, were the first to insist on the true nature of these plant-like animals.† It was, however, in this town (Brighton) that, in the year 1752, the animal nature of many of the Zoophytes which abound on the Sussex coast was first established.‡ Mr. Ellis,§ an eminent Naturalist, was engaged in forming a collection of marine plants, and, having occasion to examine some of the specimens through a powerful microscope, he was astonished to find that the Sponges, at that time supposed to be vegetables, possessed a system of pores and vessels through which the sea-water circulated; and that many of the Bryozoa exhibited cells, from which tentacula or feelers were constantly protruding, and then suddenly retracting, as if seizing and devouring prey. Subsequent observations have proved that the substance we call "sponge" is the skeleton, or support, of a gelatinous and vascular, or sometimes granular, substance which invests it, and which may be considered as the flesh of the animal.‖ When viewed through the microscope, innumerable pores are seen on the surface of the Sponge constantly imbibing salt water, which circulates throughout the mass, and is finally rejected from the large openings; this water doubtless contains the living atoms that constitute the food of this zoophyte, but which are so minute as to

* Phil. Trans. Abridg. vol. x. p. 257.

† For the history of the researches of Naturalists among the Zoophytes, see Dana's "Structure and Classification of Zoophytes," 1846; Blainville "Manuel d'Actinologie," 1834; and Johnston's "History of British Zoophytes," 1838, and New Edit.

‡ See Prof. Allman's Introduction to his magnificent "Monograph of freshwater Polyzoa" (Ray Soc.), 1856, for a complete history of the recognition of these Zoophytes as animals, and as forming a distinct class.

§ Author of the beautiful work on "British Corallines," &c.—long the standard authority on Zoophytology.

‖ Grant, Edinb. Phil. Journ. vol. xiii. p. 102.

elude observation. It is only of late that, after long and patient observations, Mr. Bowerbank has succeeded in demonstrating the existence of true mouth-like openings in the jelly-like coating, or sarcode, of the Sponge. These, however,—wonderful as it may appear!—are of a temporary nature; being opened in any part of the surface, apparently at the will of the animal, and at long intervals of time, and closing up again in a short time, without the least trace of them remaining.*

The Sponges, however, approach so closely in their structure to certain plants, that many eminent Naturalists have referred them to the Vegetable kingdom, believing that, if a line could be drawn between animals and vegetables, the Sponges should be placed among the latter. But these bodies appear to me to hold an intermediate place,—to be on the boundary line that intervenes between the two grand divisions of animated nature; they are, in short, true Zoophytes or Animal-plants; it will, therefore, be instructive to dwell a brief space on the investigation of their structure and economy.

The living Sponge, when highly magnified, exhibits a cellular tissue, permeated by pores, which unite into cells, or tubes, that ramify through the mass in every direction, and terminate in larger openings. In most Sponges the tissue is strengthened and supported by spines or spicula of various forms, and which, in some species, are silicious, and in others calcareous.† The minute pores through which the water is imbibed have a fine transverse gelatinous net-work, and projecting spicula, by which large animalcules or noxious particles are excluded; water incessantly enters into these

* Bowerbank, Brit. Assoc. Reports, 1856, p. 438; and 1857.

† For descriptions of the Spicula of Sponges, see Prof. Quekett's Lectures on Histology; and his Catalogue of the Histological series in the Museum of the College of Surgeons, p. 177, &c., pl. 10, 11. Mr. Bowerbank's forthcoming History of the British Sponges (Ray Society) will supply full details of all these curious organic structures.

pores, traverses the cells or tubes, and is finally ejected from the large vents. But the pores of the sponge have not the power of contracting and expanding, as Ellis supposed; the water is attracted to these openings by the action of instruments of a very extraordinary nature (cilia), by which currents are produced in the fluid, and propelled in the direction required by the economy of the animal.*

8. CILIA,† OR VIBRATILE ORGANS.—Although these organs, which are termed *Cilia* from their hair-like appearance, are not confined to the class of animals which form the subject of this inquiry, yet they play so important a part in the economy of Zoophytes and all other animals, that it will be necessary to define their structure and functions. These processes resemble very slender fibres or hairs, and are only visible under a powerful microscope. They are situated on parts habitually in contact with water or some other fluid, and possess the power of performing a rotatory or circular oscillation with great rapidity, by which they produce currents and eddies in the surrounding fluid.

When a drop of water containing Infusoria is brought under the microscope, it is seen that, as the creatures move along, every particle of foreign matter near them is agitated, a phenomenon indicating eddies in the water. When the animalcules remain stationary, the currents are more distinct, and evidently take certain directions, causing the particles of matter to run in a stream to and from the animal. If a very high magnifying power be employed, transparent filaments will be distinguished projecting from the surface of the animalcules, and moving with extreme rapidity. These are the Cilia, which serve to assist in progression, and when the animal is stationary, impel the water in currents through the cavities and tubes on which they are distributed: these must not be mistaken for the tentacula, or feelers, for they are fringes of delicate fibres investing those instruments and the internal surfaces of other organs. The Cilia are so minute, that their outward form, position, and the direction of their motions only can be detected, their internal struc-

* Dr. Grant, Mr. Bowerbank, and some other Naturalists affirm the existence of vibratile cilia in Sponges. See Gosse's "Life," p. 4, and p. 34, &c.

† From *cilium*, an eye-lash.

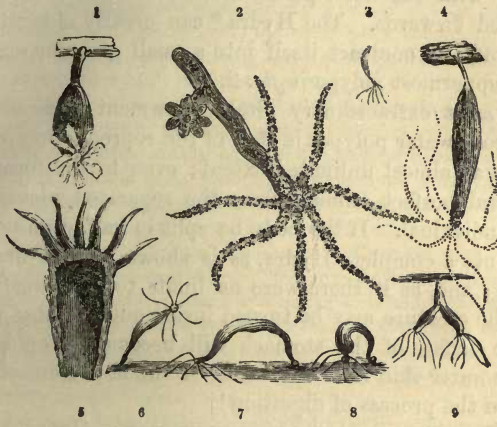
ture eluding observation. In the simplest animal organisms they are the organs by which motion and respiration are effected, and the food necessary for nutrition obtained. But they exist also in Man and the higher orders of vertebrata, and are the instruments by which many of the most important functions of the animal economy are performed. As we cannot separate the idea of muscular fibre from animal motion, it is conjectured that the Cilia are impelled by definitely arranged muscles: and Ehrenberg believes he has detected these muscles in some of the larger Infusoria.* The number of the cilia, even in an animalcule invisible to the naked eye, is almost incredible; Dr. Grant calculates that a single polype of a Flustra has 400 millions.

9. THE HYDRA, OR FRESH-WATER POLYPE.†—Before describing the zoophytes which are the immediate subject of this Lecture, I would call your attention to one of the most simple forms of animal life that abounds everywhere in fresh-water streams, and, being relatively of considerable size, will afford a convenient illustration of some of the vital phenomena exhibited in the coral-zoophytes which give rise to reefs and islands in the seas of warm climates, and of one group of which (the *Hydroida* or *Sertularidæ*) it is the simplest form and type. This is the *Hydra*, or fresh-water polype, of which two or three kinds inhabit our ponds, rivulets, &c. They are generally attached to the stems and leaves of aquatic plants; and the largest species, when in an expanded state, is from a quarter to half an inch long, and of the size of a hog's bristle; it is constricted at the end attached to the plant, and has an aperture or mouth at the free extremity, from around which proceed from six to ten

* See the representation of the Cilia on the rotatory organs of the Rotifer or Wheel-animalcule in "Thoughts on Animalcules," p. 35. The continuance of the ciliary motion in parts separated from the rest of the body of *Mytilus* and many other animals, and even for some time after death, proves that the action is automatic, or independent of the will of the animal.

† Polype, or polypus (*many feet*), is a name derived from the tentacula or processes which in some species serve for progression, in others for respiration. The name has been also applied to some of the many-armed Cephalopods.

long delicate tentacula (*Lign.* 139, *fig.* 4). The *Hydræ* present an example of a highly endowed organism of the simplest structure; the whole animal consisting merely of a gelatinous, transparent, open cylinder, or tube, contracted at one extremity, and having the margin of the other prolonged into tubular tentacula. It is, in fact, a stomach, or digestive sac, with no appendage but the instruments for



LIGN. 139.—HYDRÆ OR FRESHWATER POLYPES.

(The type of the Hydroid or Sertularian Corals.)

Fig. 1. *Hydra fusca* magnified, the tentacula partially expanded. 2. Two Hydræ on the same base, one contracted, the other expanded. 3. *Hydra viridis*, natural size. 4. Hydra, with the body enlarged from its containing food. 5. Vertical section of *Hydra viridis*, highly magnified. 6, 7, 8. Hydræ in various states of progression. 9. A double Hydra, produced by the vertical section of a single one.

seizing its prey. A vertical section (*Lign.* 139, *fig.* 5), highly magnified, shows the interior of the receptacle for the food, the relative thickness of its substance, and the manner in which the tentacula are formed by an extension of the upper margin. The Hydra is endowed with vitality in a very extraordinary degree, and its substance is highly sensi-

tive and contractile in all its parts. It fixes itself to other bodies by the small end of the tube, and expands and contracts at pleasure. These enlarged drawings (*Lign.* 139) represent the polypes in different positions and states of contraction. The mode of progression is shown in *figs.* 6, 7, 8; it is effected by the bending of the body into a curve, and holding by the tentacula; the base is then brought into contact with the fixed point, and the tentacula are again projected forwards. The Hydra * can greatly elongate the body, and also contract itself into a small globular mass, as in the uppermost polype in *fig.* 2.

The most extraordinary vital endowment possessed by these fresh-water polypes is that of the reproduction of lost parts to an almost unlimited extent; even to the formation of several perfect animals from the separated pieces of a single individual. If the body be split in half, each portion grows into a complete Hydra, as is shown in this drawing (*fig.* 9); and, as if there were no limits to its transformations, the creature may be turned inside out, and that which was the surface of the stomach will become the epidermis, and the outer skin form the lining of the new stomach, and carry on the process of digestion! †

10. ELEMENTARY ORGANIC STRUCTURE; CELLS. — The interpretation of these phenomena is to be found in the peculiar organization of the Hydra, its entire structure being nothing more than an aggregation of cells.

A vertical section of the Polype (*Lign.* 139, *fig.* 5) shows the internal cavity or digestive sac, the relative thickness of the substance of the body, and the manner in which the arms are formed by a prolongation of the upper part into hollow processes. This animal is, in fact, a simple sac or pouch formed of a congeries of cells, for the reception and assimilation

* See "Thoughts on Animalcules," Pl. I., for coloured figures of the Hydræ.

† Abraham Trembley of Geneva, in 1740, first observed this wonderful property of the Hydra. See his work, "Mémoires pour servir à l'Histoire d'un Genre de Polypes d'Eau douce." 4°. Leyde, 1744.

of food. The cells lining the stomach select and absorb the nutritious particles, and the tube then spontaneously contracts and casts out the residue of digestion. This organization is analogous to that of the simplest condition of the vegetable kingdom, the *Cellulosæ:* for even the large *Fuci*, or sea-weeds, consist only of cells. The fresh-water *Confervæ* are merely jointed films composed of cells, containing granules or lesser cells. A cell bursts, the granules escape, and float in the water until they become fixed to some other body; they then reproduce cells, which are aggregated after the same pattern as in the parent plant. The common mould or mustiness is a cluster of plants formed of cells only; and there are some vegetables in which the entire plant consists of but *one isolated cell;* such as the red snow (*Leparia nivalis*); whilst in the yeast-fungus (*Tortula cerevisiæ*), the plant consists of but one, two, three, or a few more. In these examples we see that all the functions of vegetable life, namely, absorption, assimilation, the fixation of carbon from the atmosphere, respiration, exhalation, secretion, and reproduction, can be effected by one single cell. Even in the highest and most complicated orders of vegetables, in which there is a variety of organs adapted for the performance of different offices, these functions are effected by the agency of cells, which obtain materials of formation and support from the ordinary chemical agents around them. Thus an aggregation of simple cells forms the cellular tissue; a fusion or blending of several cells produces the vessels, and so forth; and by cells are elaborated the gum, resin, oil, starch, gluten, &c.: and by cells specially endowed are secreted the narcotic substance of the poppy, the deadly poison of the nightshade, and the stimulant aromatic of the clove.

In like manner, in animal structures, all the various processes of vitality are performed by cells or globules, varying in size from infinite minuteness to forms visible to the unassisted eye. Thus one system of cells secretes the bile, another the adipose substance, another the nervous matter, and so forth; but how these special products are formed by cells apparently of similar organization we know not. Whether the special endowment belonging to the system of cells of a particular organ depends on the intimate structure of the wall or tissue of such cells, and this structure be so attenuated and infinitesimal as to elude our observation,—or whether it results from the transmission of some peculiar modification of that mysterious vital force we term nervous influence,—are questions to which, I apprehend, no satisfactory reply can be given.

In fine, a minute globular cell is typical of the common germ from which all organic fabrics proceed. All animals and plants, therefore, may justly be regarded as definite aggregations of cells, endowed with specific properties in the different types, and subjected to a never vary-

ing law of development; and in animals, as well as in plants, there are certain kinds in which the entire organism consists of but a single cell;* and others in which each individual is but a cluster of such cells arranged in a definite manner. These mere aggregations of cells perform all the functions of animal life, viz. the maintenance of a particular form for a certain period, the elaboration of materials of support from food, locomotion, and the perpetuation of the species; hence these animals, like the simplest plants, may be divided without losing their vitality, and every part may become a perfect individual. To this class of organization belongs the Hydra; and the above exposition of its structure renders the production of several animals from the vivisection of an individual perfectly intelligible.

11. ANALOGY NOT IDENTITY.—And here I must briefly comment on the doctrine of the *law of development*, as it is termed, so speciously, but unphilosophically, advocated in a late work;† in which it is attempted to show, that all the varied forms of organic life are the result of a law by which is produced an unbroken chain of gradually exalted organization, from the crystal to the globule, and thence through successive stages of the polype, mollusk, &c., up to Man.‡

The following remarks will serve to show the fallacy of this reasoning. Though it is an established physiological axiom, that cells are the elementary basis, the ultimate limit to which we can trace all animal and vegetable structures, and that the varied functions in which organic life essentially consists are performed by the agency of cells not distinguishable from each other by any well-marked characters, there is not the slightest ground for assuming any identity between the primary cells of the simplest species of animals and vegetables, much less those of higher

* The Monads: see "Thoughts on Animalcules," Plate II.

† Vestiges of the Natural History of the Creation.

‡ The following remarks of Sir John Herschel on this theory are too important to be omitted. "The transition from an inanimate crystal to a globule capable of such endless organic and intellectual development is as great a step—as unexplained a phenomenon—as unintelligible to us—and in any human sense of the word as *miraculous*, as would be the immediate creation and introduction upon earth of every species and every individual. Take the amazing facts of Geology which way we will, we must resort elsewhere than to a mere speculative law of development for their explanation."—*Brit. Assoc. Report for* 1845, p. 42.

organization. The single cell which embodies vitality in the yeast-fungus or the monad is governed by the same immutable organic laws which preside over the complicated structure of Man and the other vertebrata: and the single cell which is the *embryotic* condition of the Mammal has no more relation to the single cell which is the *permanent* condition of the monad, than has the perfect animal into which the mammalian cell is ultimately developed. The cell that forms the germ of each species of organism is endowed with special properties, which can result in nothing but the fabrication of that particular species. There is an *analogy* between the human embryo and the monad of the Volvox, in that each consists of simple cells; but there is no more *identity* between the human and infusorial cells than between the perfect Man and the mature Animalcule.*

12. THE BRYOZOA.—From this digression we return to the consideration of the Zoophytes, and especially of the *Bryozoa*, which stand first in order among the plant-like animals, and are well called Moss-animals on account of their aggregated masses incrusting other bodies like moss. They present numerous fresh-water species,† as well as an extraordinary abundance of marine forms. Their polypes, though exceedingly minute, are highly organized, their digestive organs being more complicated than those of the other tribes of Zoophytes.‡ I will select one of the most simple and common forms in illustration of the subject. Most persons in their rambles along the sea-shore must have noticed on the seaweeds, shells, and pebbles patches of a white reticulated substance, which, when closely examined, appear like delicate lace-work: these, apparently mere earthly particles, are clusters of the compound zoophytes termed *Flustra*§ or "Sea-mat." (*See Plate* V. *figs.* 5, 6, 7, 8.)

* See Notes to "Thoughts on Animalcules;" and Westminster Review, No. XC. Art. "The Microscope and its Revelations."

† Most philosophically described and most beautifully illustrated by Prof. Allman in his "Monog. Fresh-water Polyzoa," 1856 (Ray Society).

‡ See above, p. 601.

§ The word *Flustra* is here intended to comprise the closely-allied genus *Membranipora*, as formerly, for the sake of convenience of reference and description.

The Flustra,* when taken alive out of the water, presents to the naked eye the appearance of fine net-work, coated over with a glossy varnish (*Pl.* V. *fig.* 5); with a glass of moderate power, the surface is discovered to be full of pores, disposed with much regularity (*Pl.* V. *fig.* 8). If a magnifying glass be employed while the Flustra is immersed in sea-water, very different phenomena appear; the surface is found to be invested with a fleshy or gelatinous substance, and every pore to be the opening of a cell, whence issues a tube with several long feelers or arms (*Lign.* 140); these expand, then suddenly close, withdraw into the cells, and again issue forth; the whole mass being studded with these hydra-like forms. The Flustra thus constitutes, as it were, a family of polypes, each individual of which is permanently fixed in a calcareous cell, and the whole united by a common integument, by which the hard frame-work was secreted. Under a powerful microscope the form and structure of the animal of the Flustra may be easily distinguished. *Pl.* V. *fig.* 6, represents a single polype with its tentacula extended; and *fig.* 7, the same animalcule, withdrawn into its cell. The figure, *Lign.* 140, shows a polype protruded, under a much higher power.†

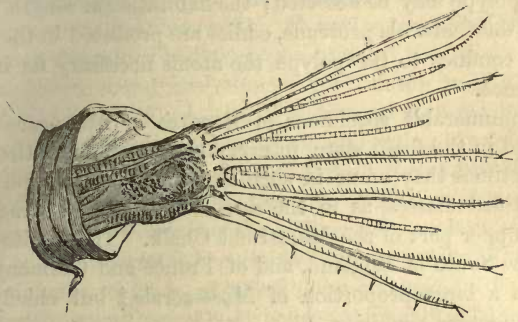
The body of the animalcule consists of a transparent sac or pouch, doubled on itself, and having at the mouth, or large external opening, ten or twelve tentacula fringed with cilia, which have the power of extending and contracting themselves with great celerity.

The Flustroid Bryozoa present considerable variety in the

* For the latest technical descriptions, and detailed illustrations of the recent *Flustræ* and their allies, see Johnston's *Brit. Zoophytes*, 2nd Edit. p. 342; Busk's *Polyozoa Brit. Mus.* p. 46; and Alder's *Cat. Zoophyt.* p. 139.

† This figure is from a memoir by Mr. Lister (Philos. Trans. 1834) on the structure and functions of the Tubular and Cellular Polypes. The observations were made at Brighton, and I had the pleasure of seeing the live zoophytes under the fine instrument constructed by Mr. Lister.

form and arrangement of their cells. Some of the most common species are found attached to marine plants, which they enclose, as it were, in a living sepulchre (*Pl.* V. *fig.* 5); others spread into foliated expansions, and have both sides covered with cells. The prevailing hue is white, or a light-fawn colour, but some species have a tinge of pink or



LIGN. 140.—POLYPE OF FLUSTRA* PILOSA; WITH ITS MOUTH AND CILIATED ARMS PROTRUDED FROM THE CELL.

(Magnified 150 times.)

yellow. Numerous species† resemble in miniature the branching tree-like forms of the Corals, or other coralloid and spongoid shapes. They abound in every sea, are not restricted by climate, occur in profusion along the sea-shores, and are found attached to the fuci that are thrown up from below low-water mark.‡ The small parasitical species, when dried, appear like spots of a chalky substance on the sea-weed.

* *Membranipora*, Busk, Polyz. Brit. Mus., p. 56, pl. 71.

† Medals, p. 268, *fig.* 89.

‡ A concise notice of the distribution of Molluscous animals in the several "zones" into which naturalists have divided the bed of the sea, will be found in Woodward's "Manual of the Mollusca," p. 439: and in Mr. J. Alder's "Catalogue of the Zoophytes of Northumberland and Durham" (Trans. Tyneside Nat. Field Club, vol. iii. p. 98), the reader will find upwards of 200 species of British Anthozoa and Bryozoa arranged according to their distribution into zones of depth.

The increase of the Flustra is thus described by Lamouroux. —When the animal has acquired its full growth, it flings from the opening of its cell a small globular body, which fixes near the aperture, increases in size, and soon assumes the form of a new cell; it is yet closed, but through the transparent membrane that covers its surface the motions of the polype may be detected; the habitation at length bursts, and the tentacula protrude, eddies are produced in the water, and conduct to the polype the atoms necessary for its subsistence.

Innumerable specimens of Bryozoa or Moss-corals* are found in the fossil state, in every geological formation; and sometimes they occur in such abundance as to form whole stratified masses, as in the case of the Suffolk Crag,† and the upper part of the Maestricht Chalk. The White Chalk of the South of England, and of France and Germany, contains a large proportion of Moss-corals,‡ but chiefly in a fragmentary condition.

The *Graptolites*,§ found in the Silurian rocks, have been referred by some authors to the Bryozoan group; by others, however, they have been placed with the *Virgulariæ* of the Alcyonarian order.

13. THE FOOD OF ZOOPHYTES.—However improbable it may appear to the mind unaccustomed to investigations of this nature, that beings so minute as those under examination should prey upon living forms yet more infinitesimal, the fact is nevertheless unquestionable. It is even possible to select the food of animalcules much smaller than the

* Medals, p. 265. From the imitative resemblance of many of their little polyparies to those of the larger Corals, the Bryozoa are often referred to by the above name.

† This was formerly termed "Coralline Crag," owing to the then imperfect state of the nomenclature of the Zoophytes. See vol. i. p. 224.

‡ See vol. i. p. 331. Also D'Orbigny's "Paléontol. Française;" and Hagenow's "Die Bryozoen der Maastrichter Kreidebildung."

§ Medals, p. 255.

polypes of the Flustra, and thus exhibit their internal structure. This experiment is easily shown under a good microscope, and the animalcules termed *Vorticellæ*, a very abundant family of Infusoria, are best adapted for the purpose. Immediately on a minute particle of a very attenuated solution of pure carmine or indigo being applied to a drop of water containing a group of the *Vorticellæ*,* the most beautiful phenomena are observable. Currents are excited in the fluid in all directions by the rapid motion of the cilia, which form a crown round the anterior part of the body of the animalcules, and the particles of indigo are seen moving in different directions, but generally all converging towards the orifice or mouth, which is situated not in the centre of the crown of cilia, but between the two rows of these organs, which exist consecutive to one another. The attention is no sooner drawn to this interesting spectacle, than presently the bodies of the animals, which were before quite transparent, become dotted with distinctly circumscribed spots, of a dark-blue colour, exactly corresponding to that of the moving particles of indigo. In some species, particularly in those which are provided with an annular contraction or neck, separating the head from the body, the molecules of indigo can be traced in a continuous line in their progress from the mouth to the internal cavities.

The animalcules termed *Monads* may be considered as the lowest term of animal organization recognisable by man, being only from the 1,200th to the 24,000th part of an inch in diameter, and the powers of the microscope extend no farther; yet it is impossible to doubt that there are myriads of living forms more infinitesimal, some of which serve as food to these miniatures of life.†

* The Vorticellæ are hyaline vase-shaped or bell-like animalcules, attached by a slender peduncle at the base, and having rows of cilia disposed in zones round the margin; these, when seen in some directions while in rapid motion, appear like wheels. See "Thoughts on Animalcules," Pl. III.

† "The size of the ultimate particles of matter must be small in the

14. NATURE OF ZOOPHYTES.—In the larger and free masses of Flustra, the decomposition of the animal substance after death is very manifest. This specimen of *Flustra foliacea*, which was dredged up twenty miles SSW. of Brighton, in water eighteen fathoms deep, is a fine example of this brittle species; when first in my possession it was highly offensive from the emanations evolved during the decomposition of the animal matter. It is now a flexible calcareous skeleton, with here and there portions of the shrivelled integument, but, of course, without any traces of polypes in the cells.

Let us now refer to our previous remarks, and inquire if the Flustra presents the essential characters of animal existence. Its polype possesses a determinate form, and has a calcareous skeleton covered by a soft fleshy substance, that can for a certain period resist chemical and mechanical agency. It is furnished with instruments capable of moving with great celerity, is susceptible of external impressions, and can expand and contract at will. Here, then, is evidence of sensation and of voluntary motion; and although, from the extreme minuteness of the structure, nerves cannot be detected, yet there can be little doubt that it possesses a nervous and also a circulatory system for effecting nutrition and reparation. We find, also, that, when removed from the element in which it lived, the creature dies, and its soft substance, like the flesh of the larger animals, undergoes putrefaction; it has lost the vital principle by which it previously resisted chemical agency, and now submits to the effects of those laws which act upon inorganic matter; the

extreme. Organized beings, possessing life and all its functions, have been discovered so small that a million of them would occupy less space than a grain of sand. The malleability of gold, the perfume of musk, the odour of flowers, and many other instances might be given of the excessive minuteness of the atoms of matter: yet, from a variety of circumstances, it may be inferred that matter is not infinitely divisible."—*Mrs. Somerville*, p. 125.

calcareous and horny materials that composed its skeleton, and which, like the bones of mammiferous animals, were secreted by the soft parts, alone remain.

I would here particularly remark, that the stony support of all Zoophytes is formed by a similar process; the hard substance called *coral* being secreted by the integuments or membranes with which it was permeated and invested, in like manner as the bones and nails in man are secreted by the tissues designed for that purpose, and acting without his knowledge or control. Nothing can be more erroneous than the popular notion that the cells of corals are built up by the polypes found in them in the same manner as are the cells of wax by the Bee.

From what has been advanced, it is evident that the Flustra is an aggregation of an immense number of individual polypes attached to a calcareous or horny skeleton, and each of which is doubtlessly susceptible of pain and pleasure independently of the whole; for we have a living proof in the Siamese twins,* that even in our own species there may be a united organization with separate nervous systems, and individual sensations; and, as it is certain that each polype enjoys distinct volition, it is most probable that the sensations of each individual are independent of the general mass. There is, however, a common sensibility pervading the structure that binds together the community of zoophytes, and by which certain actions are performed irrespectively of the individual polypes. Thus the compound zoophytes termed *Pennatulæ*, or Sea-pens,† upon the slightest touc withdraw themselves into the wet sand, and disappear: and the arborescent *Vorticellæ*,‡ upon the microscope being agitated, instantly shrink down into a globular mass, and all appearance of the elegant animalcules, a mo-

* See the Philosophical Transactions for 1830, p. 177.

† Belonging to the *Alcyonaria*.

‡ See "Thoughts on Animalcules," p. 49.

ment before so active, vanishes. In certain species of Bryozoa (*Bugula flabellata*,* for example), each cell is accompanied by a bivalved appendage, much resembling in form the beaks and head of a vulture, and termed the "avicularium;" and these appendages open and shut apparently without the control of the polype that occupies the cell; their functions seem to be related to the horny axis that connects the group of independent living animalcules of which the entire compound zoophyte is composed, and not to the polypes themselves.†

15. THE CORALS, OR POLYPIFERA.—The Corals, or *Polypifera* (Zoophytes proper), present an extensive series of varied and extraordinary forms of zoophytal organization. In some, the skeleton‡ or support consists of various combinations of earthy and animal matter, as it is in the Flustra, but solid and hard as stone; in many examples it branches out like a tree (*Lign.* 143, p. 624); in others, it constitutes hemispherical masses, having numerous convolutions on the surface, somewhat resembling in appearance the brains of quadrupeds (*Lign.* 144); and in many it forms an aggregation of tubes, terminating in star-like openings (Pl. VI. *fig.*

* Formerly known as *Flustra avicularis*. See Busk, *op. cit.* p. 44, pl. 51, 52.

† The reader will find some highly interesting observations on this phenomenon in Mr. Darwin's "Journal of a Voyage round the World," chap. ix. p. 200. Mr. Gosse has suggested that possibly the use of the *avicularia* may be to fortuitously catch and to hold minute animals until, attracted by their decomposition, hosts of other animalcules swarm in the neighbourhood and come within the currents produced by the ciliated tentacles of the zoophytes themselves.

‡ The axis, framework, or skeleton of these groups of polypes is termed *polypary*, or *polypidom* (polype-habitation); and those of a stony hardness are familiarly known as "Coral:" these names therefore refer to the durable skeleton of the zoophytes, and not to the polypes themselves; but in familiar writing the term Coral is often used to designate the entire living mass. In a fossil state the *polyparium* alone remains, except in a few instances. See "Medals of Creation," chap. vii.

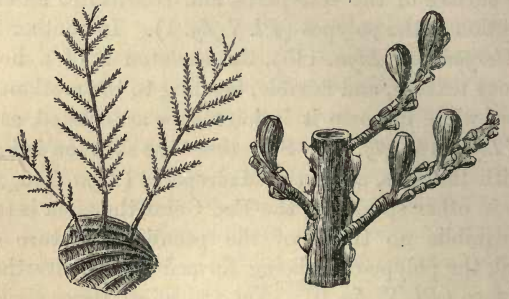
9). Among the branched varieties, some are covered by pores so numerous as to be called *Millepora:* in many, the openings are distant: some have star-like markings here and there; while in others, the whole surface presents a stellated structure. In many species the fleshy animal matter entirely covers and conceals the stony skeleton during life; in others, the latter becomes exposed, and forms a trunk, having branches covered by living polypes; while in another and numerous division (of which the common *Sertularia* is an example), the skeleton is flexible, and is secreted by the outer surface of the soft parts, and constitutes an external protection to the polypes (*Pl.* V. *fig.* 1). In another family, the *Gorgonidæ* (*Lign.* 145), the skeleton is of a horny or ligneous texture, and flexible, bending to the motions of the waves; while in some it is jointed or articulated, as in the *Isis* (*Lign.* 143, *fig.* 3). Sometimes the skeleton is impressed with the cells, as in the Madrepores (*Lign.* 143, *fig.* 2); while in other species, as the Red Coral, the stem is smooth, and exhibits no traces of the peculiar structure of the animal, the polype-cells being formed of the investing soft substance (*Pl.* V. *fig.* 9). Yet amidst all these varieties of form, the same essential characters are maintained; in all there is a skeleton or solid support, and a fleshy or gelatinous substance, either investing the polypidom and studded with polypes having more or less simple stomachal cavities; or constituting separate polypes, but more or less intimately connected by imtermediate animal and calcareous matter.

16. THE SERTULARIAN ZOOPHYTES.* — The *Hydra*, as above mentioned, p. 606, is regarded as the type of the Sertularian Zoophytes;† and, supposing it to be invested with a

* For the classification and description of the members of this group, the reader is referred to Johnston's "British Zoophytes," 2nd Edit.

† There have been of late years discovered some remarkable points of alliance between these Hydroid zoophytes and the Acalephs (*Medusæ*, &c.).

horny coat, to be elongated by growth, and to retain all the buds, or young Hydræ, which are formed on its axis or stem throughout life, we might regard it as truly analogous to a *Sertularia*. The elegant arborescent *Sertulariæ* must be familiar to every one who has rambled by the sea-side. This branch of the Sea-pine (*Lign.* 141), part of which is shown magnified in *fig.* 2, exhibits the usual appearance of these zoophytes. The Sertularia consists of tubes united together, and having lateral apertures for the protrusion of each polype; one elegant species, the *Sertularia setacea*, is very



1 2

LIGN. 141.—SERTULARIA NIGRA (JOHNSTON).

Fig. 1. Natural size. 2. A portion highly magnified (the tentacles not being protruded from the cells).

abundant on the shores at Brighton after storms, being attached to fuci and other sea-weeds. The representation of a branch, magnified sixty times, in *Plate* V. *fig.* 1, shows the form of the polypes, which, when fully expanded, are of great beauty. On one occasion, when I was present, Mr. Lister was observing a living specimen, when a little globular animalcule swam rapidly by one of the expanded polypes; the latter immediately contracted, seized the globule, and brought it to the mouth or central opening by its tentacula;

these gradually opened again, with the exception of one which remained folded, with its extremity on the animalcule. The mouth indistinctly seemed filled with hairs or tentacles, that closed over the prey, which, after a few seconds, was carried slowly down into the stomach; here it was imperfectly seen, and soon disappeared.*

The *Campanulariæ*, so named from their *bell-shaped* cells placed on foot-stalks, also belong to the Hydroid polypes, and are abundant on our shores. *Pl.* V. *fig.* 2, is a magnified view of a branch of *Campanularia gelatinosa*, with several cells; in some the polypes are expanded, in others contracted. Examined alive under the microscope, currents of minute globules are seen constantly running along the tubes, induced by the action of the invisible cilia.

17. The Actinoidea, or Corallaria.†—Having described some of the principal characters of the Hydroid or Hydrarian Polypifers, the lower group, in which digestion is performed by a simple sac or pouch, as in the common *Hydra*,‡ we proceed to indicate the leading forms of the two other great groups§ (the Helianthoid or Zoantharian Corals, and the Alcyonarian group), with some remarks on their nature and habits. In the Corals proper, the framework or polypary is generally calcareous; the species of the soft-bodied Zoantharia (or Actinidæ) being of a limited number; whilst the stony or "coralligenous" Zoantharia have very numerous species, both in the fossil and the re-

* Philos. Trans. 1834, p. 372.

† Milne Edwards and Haime, Monog. Brit. Foss. Corals (Palæont. Soc.), 1850, p. ix.

‡ See Owen's Lectures on the Invertebrata. Of the many notices and monographs of the *Hydra*, Corda's memoir in the *Nova Acta Acad. Nat. Cur.* vol. xviii., may be referred to as one of the amplest and most fully illustrated.

§ There is a third group or order, the *Podactinaria* (Edwards and Haime), represented by one genus only, the *Lucernaria*.

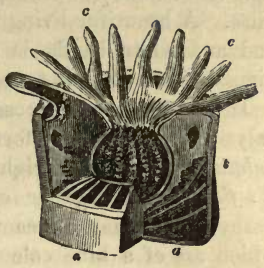
cent state.* The *Actinoidea* vary considerably in relative size, and present every state of combination, up to the enormous aggregations of individuals existing in the reef-forming species. The polypes, too, vary greatly in size, from being microscopic to having a diameter of eighteen inches.

The stony Corals present polypes which are readily found, on examination, to present a close analogy to the *Actiniæ*, or Sea-anemones, which are so common on the rocks and in the shallows of our sea-shores; a few observations on these latter animals will therefore enable us to comprehend the nature of this group of polypifera. The Actinia, or *Sea-anemone*, appears, when quiescent, like a subglobular mass of tough jelly, of various tints of crimson, green, blue, or brown (*see Pl.* VI. *fig.* 11); when expanded, it presents a broad disk, surrounded by tentacula, and having in the centre a corrugated surface, which is contracted into a purse-like form.

The Actiniæ are affixed to the rocks by a broad base, but they can detach themselves, and change their position; on many parts of the coast hundreds may be seen, at low water, on the rocks which are left bare by the reflux of the tide. They are carnivorous and very voracious, feeding on the small fish, crustacea, and mollusca that come within their reach. They may be kept for months in sea-water, if supplied daily with meat, which they greedily seize, draw into the sac or stomach, and afterwards eject perfectly colourless, having absorbed the juices and left the tough muscular fibre. The body of the Actinia is highly contractile and full of chambers: the tentacula are hollow tubes, which the animal has the power of filling with sea-water and

* For the classification of these Corals, see Dana's Zoophytes, p. 112; and Edwards and Haime, *loc. cit.* Numerous fossil species are figured and described by Michelin, Iconog. Zoophyt. 4to, 1847.

thus causing them to protrude. The chambers also contain water, with which the whole or any part of the body can be filled; an important agency in enabling the animal to shift its situation from place to place. The accompanying plan of the internal structure of the Actinia (*Lign.* 142) will serve to illustrate these remarks. The surface of the stomach, and even the internal lining of the tentacula, are abundantly furnished with cilia. These zoophytes have no durable skeletons.



LIGN. 142.—ILLUSTRATION OF THE STRUCTURE OF THE ACTINIA.*

a, *a*, The base by which the Actinia attaches itself. *b*, *b*, Openings of chambers which communicate with each other and with the tentacula. *c*, *c*, The tentacula. The surface of the stomach is seen in the centre, arranged in vertical plaits or folds.

18. CARYOPHYLLIA AND TURBINOLIA.—In the small recent coral, *Turbinolia rubra*, we have an example of a single calcareous cup or "calyx," divided by vertical lamellæ or partitions, arranged in a radiated manner. This is the skeleton or stony support of a single polype, which has a double row of tubular tentacula, and bears a great analogy to the Actinia; indeed, the recent animal may be described as an Actinia with a calcareous skeleton, fixed by its base.†

* Cyclopædia of Anatomy and Physiology, p. 614: see also the elaborate and well-illustrated Article on *Polypifera*, by Prof. Rymer Jones, in the same work.

† The beautifully illustrated and cleverly written works of Mr. Gosse, on the Actiniæ and other marine animals found on the Dorset, Devon, and Tenby coasts, are so well known, that we need only to allude to them as being highly important to the lover of natural history who wishes to study these animals. The philosophical comparison of *Cyathina Smithii* (a little coral found on our shores, and the only one) with *Actinia*, in Gosse's "Life," &c., is particularly recommended for study. See also "Sea-side Studies," in Blackwood's Magazine, for 1856-7.

The fossil corals (p. 330, *figs.* 1, 2, 3) possess a similar structure. A beautiful living Turbinolia, which is marked with red and white bands, is shown in *Pl.* VI. *fig.* 8: and a similar Coral with its tentacula expanded,* in *fig.* 14.

In the *Caryophyllia* possessing more than one calyx, each calyx contains an actiniform polype: one of those of *C. fasciculata*, which is of a bright green colour, is represented *Pl.* V. *fig.* 4. In another genus, *Pocillopora*, the investing fleshy integument is beautifully mottled, and the polypes, which are of a blue colour, are terminal, as in the Caryophyllia. A branch, as seen alive in the water, is figured in *Pl.* V. *fig.* 11.

19. MADREPORA.—In the Caryophyllacea, just noticed, the polypes and their containing calyces are of relatively large size; but in the family of branched or arborescent calcareous polypifera called *Madrepores*, the little cups or cells,

LIGN 143.—RECENT CORALS.

Fig. 1. A branch of *Oculina ramea*. 2. A branch of *Madrepora muricata*. 3. A branch of *Isis hippuris*: *a*, the cortical substance present and covered with pores, which are the cells of polypes; *b*, a branch deprived of its outer covering, and exposing the articulated axis or stem.

with radiating lamellæ, in which the polypes are situated, are of small size. When the animals die, and the outer

* See especially Quoy and Gaimard's Voyage de l'Astrolabe (Atlas), and Dana's Zoophytes (Atlas), for figures of corals drawn from nature.

fleshy or gelatinous investment perishes, the coral is found to be studded over with elegant, lamellated, stellular cells, variously formed and arranged in the different genera and species. In some the cells are very distinct; as in a Mediterranean species, the *May-blossom Coral* (*Oculina ramea*, *Lign.* 143, *fig.* 1); in others they are exceedingly minute, as in the common Madrepore (*M. muricata*, *Lign.* 143, *fig.* 2), from the West Indies: the white-branched corals, so numerous in collections, belong for the most part to this group.

When alive in the water, the Madrepores are invested with a fleshy integument of various colours; and each cell is occupied by a polype, as in the zoophytes previously described. The appearance of a living Madrepore (*Madrepora plantaginea*), with the polypes protruded, is shown in *Pl.* VI. *fig.* 5, and will serve to convey a faint idea of the beautiful appearance of the live corals in their native element.

20. Fungia. — The white, disciform, lamellated corals, called Sea-mushrooms, or *Fungiæ*, from their fancied resemblance to fungi, are among the most elegant and abundant forms of corallaria in the cabinets of collectors. These, in a living state, are covered with a thick, transparent, jelly-like substance, which fills up all the numerous radiating interstices of the calcareous laminæ; in the central depression of the fleshy mass is situated a large polype with tentacula; in the Fungia, there is but one polype—but one focus of vitality. In the *Fungia actiniformis* (*Pl.* VI. *fig.* 15), the polype strikingly resembles the Actinia; the whole surface of the disk is covered with long, tubular, conical, prehensile tentacula, with minute terminal apertures, and striated, transverse, muscular bands; these tentacula are protruded by the injection of water from below, as in the Actinia. In the Fungia the stony base is secreted from the inferior surface of the soft substance, and is either attached or cemented, as it were, to the rock, or lies free on the sea-bed.

21. Astræa, Pavonia, &c.—In some of the large stony

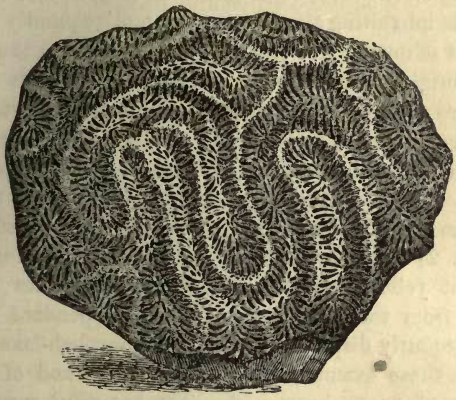
corals, the cells of the polypes are very numerous, and the coralline mass presents a surface beautifully marked with stellular impressions. The *Astræa viridis* is here represented as seen alive in the sea (*Pl.* VI. *fig.* 13). The polypes in this coral are of a dark-green colour, six lines in length, and are protected by deep, laminated, polygonal cells, two lines in diameter. They are striated with longitudinal and transverse bands, and connected by a fleshy layer which covers the dark-brown coral; some of the polypes are here shown expanded, and others contracted. In this magnified view (*Pl.* VI. *fig.* 10) of a single polype, the tentacula are seen expanded, or disposed around the prominent mouth. The appearance of groups of Astrææ, and other corals, when viewed while the animals are alive and in activity, is most beautiful; looking down through the clear sea-water, the surface of the rock appears one living mass, and the congregated polypes present the most diversified and vivid hues.*

The *Pavonia* are those corals which have deep and isolated cells, each containing a large depressed polype, very similar in its appearance and structure to the Actinia. *Pl.* VI. *fig.* 11, represents a group of cells containing polypes of the *P. lactuca*, from the shores of the South Sea islands. The polypes are of a green colour, and there is a connecting, transparent, fleshy substance, which extends over the extreme edges of the foliated expansion of this elegant zoophyte.

22. MÆANDRINA CEREBRIFORMIS; or *Brain-coral.*—The large hemispherical corals, having the surface covered with meandering ridges and depressions, disposed in a manner somewhat resembling the convolutions of the brain, are well known by the name of the *Brain-stone Coral* (*Lign.* 144). In a living state the mass is invested with a fleshy substance, variously coloured, and having numerous, short, conical, polypiform, confluent cells, arranged in rows between the

* Dana's Zoophytes, p. 29.

ridges. This zoophyte sometimes attains considerable magnitude; a very beautiful specimen in the British Museum is four feet in circumference. The base of the Mæandrina, like that of other corals, is adherent to the rock. As one



LIGN. 144—BRAIN-STONE CORAL.

(Mæandrina cerebriformis.)

fleshy mass expires, another appears, and gradually expands, pouring out its calcareous secretion on the parent mass of coral; thus successive generations go on accumulating vast beds of stony matter, and laying the foundations of coral-reefs and islands. We may compare, observes Sir C. Lyell,* the operation of the zoophytes in the ocean to the effects produced on a smaller scale on land by the plants which generate peat, where the upper part of the *Sphagnum*, or peat-moss, vegetates while the lower is entering into a mineral mass, in which the traces of organization remain when life has entirely ceased. In these Corals, in like manner,

* Principles of Geology.

the more durable materials of the generation that has passed away serve as the foundation over which their progeny spreads successive accumulations of calcareous matter.

23. ALCYONARIAN ZOOPHYTES : GORGONIA, OR SEA-FAN.—The *Gorgonia flabellum*, or Venus's fan (*Lign.* 145), is a flexible zoophyte inhabiting almost every sea, and frequently attaining a height of four or five feet. When fresh from the water it is of a bright yellow colour. This species exhibits the usual structure of the corticiferous polypifera, or zoophytes having an internal axis or skeleton of a tough horny consistence, with an external envelope or rind entirely investing the former. The Gorgoniæ present great diversity of form and appearance. This specimen from the West Indies (*Pl.* VI. *fig.* 2) is remarkable for its richness of colour, being a bright yellow, spotted with red; this species (*Pl.* VI. *fig.* 3), from the Mediterranean, has its pendant branches very elegantly disposed, and is of a purplish-lake colour; in both these examples the axis is black, and of the consistence of tough horn. Another beautiful species from the Mediterranean (the *Gorgonia patula* of Ellis) is of a bright red, and has the openings for the polypes disposed in two rows; a portion, highly magnified, is here represented (*Pl.* V. *fig.* 3), and exhibits several polypes in different states of protrusion.

These flexible Alyconaria are mostly attached to the rocks by an extended base, the surface of which is usually deprived of the fleshy substance that invests the other parts. The stem which springs from the base, although in a few species simple, generally divides into branches, which are exceedingly various in their size and distributions:—double, single, anastomosed, pinnated, straight, and pensile; and the stems are either compressed, flat, angular, or cylindrical; but in all these modifications the same structure prevails—an axis and an external crust or rind. The former is either horny, elastic, flexible, brittle, or pithy, seldom stony, and of a dark

colour; the latter a soft or tough fleshy substance, studded with pores, from which the polypes issue; this rind becomes

LIGN. 145.—GORGONIA FLABELLUM; *one-twentieth nat. size.*

earthy and friable when dried. In the *Isis*, which may be described as a Gorgonia with a jointed stem, this structure is well displayed, as in this branch of *Isis hippuris* (*Lign. fig.* 3, p. 624), in which a portion of the cortical part is removed, and the axis exposed. In the water the various species present the most vivid hues of red, green, violet, and yellow. The Gorgoniæ inhabit deep water, and are found in every sea; but certain species appear to be restricted to tropical climates. The Sea-pens (*Pennatulæ*) have a fleshy feather-like polypary, with a bony axis, and live unattached, floating free in the water, or lying on the sea-bottom, more or less imbedded in sandy mud.

Numerous species of the Asteroid Polypes, especially Alcyonium, Gorgonia, Pennatula, and their congeners, have calcareous spicules * imbedded in their leathery or fleshy integument, as in the Sponges. Horny spicules have been discovered in some Actiniæ.†

24. THE RED CORAL; *Corallium rubrum.*—Among the Alcyonarian or Asteroid Zoophytes are a few genera having an axis composed of a calcareous stony substance; and one genus possesses a skeleton of so beautiful a colour, and susceptible of so fine a polish, as to be largely employed for ornamental purposes. The Red Coral is a branched zoophyte, somewhat resembling in miniature a tree deprived of its leaves and twigs. It seldom exceeds one foot in height, and is attached to the rocks by a broad expansion or base. It consists of a brilliant red stony axis, invested with a fleshy or gelatinous substance of a pale blue colour, studded over with stellular polypes. This figure (*Pl.* V. *fig.* 9) represents a branch of "Coral" with several polypes, highly magnified, as seen alive in the water. The cortical or fleshy substance is removed at the extremities of the branch, and the red stony axis exposed. As the cells of the polypes are only composed of the soft animal matter which rapidly undergoes decomposition after death, no traces of their structure remain on the durable skeleton.

The Red Coral, as is well known, is of a very hard and durable texture; it is obtained by dredging in different parts of the Mediterranean and Eastern seas, and forms an important article of commerce. It varies much in hue, according to its situation in the sea: in shallow water it is of the most beautiful colour, a free admission of light appearing necessary for its full development. It is of slow growth; eight or ten years, in a moderate depth of water, being necessary for it to reach maturity. Arrived at this period,

* See Histological Catalogue, Roy. Coll. Surg. vol. i. p. 222, pl. 13; and Dana's Zoophytes, p. 53. † Histol. Catal. p. 226.

it extends but very slowly, and is soon pierced on all sides by those destructive animals which attack even the hardest rocks: it loses its solidity, and a slight shock detaches it from its base. Becoming the sport of the waves, the polypes perish, their brilliant skeleton is exposed, and cast upon the shore; the bright colour soon disappears, and the coral, reduced to fragments by the attrition of the waves, becomes mixed with the remains of shells and other marine exuviæ: in this state it is drifted inland by the winds,* and assists in forming those accumulations of the spoils of the sea, which constitute many of the modern conglomerates described in a previous lecture (pp. 83 and 90).

25. Tubipora.—This group of the Alcyonarian corals is well known from the elegance and beauty of one species (*Sarcinula musicalis*, or *Organ-pipe coral*), which is common in most collections. This zoophyte is composed of parallel tubes, united by lateral plates, or transverse partitions, placed at regular distances (*Pl.* VI. *figs.* 7, 9); in this manner large masses, consisting of a congeries of pipes or tubes, are formed. When the animalcules are alive, each tube contains a polype of a beautiful bright green colour, and the upper part of the surface is covered with a gelatinous mass formed by the confluence of the polypes; a magnified view of a polype and of sections of two tubes is here represented (*Pl.* VI. *fig.* 7). This species occurs in great abundance on the coast of New South Wales, of the Red Sea, and of the Molucca Islands, varying in colour from a bright red to a deep orange. It grows in the shape of large hemispherical masses, from one to two feet in circumference; these first appear as small specks adhering to a shell or rock; as they increase, the tubes resemble a group of diverging rays, and

* The term "æolian" has been aptly applied by Col. Nelson to the terrestrial formations resulting from the drifting action of the winds. See Quart. Journ. Geol. Soc. vol. ix. p. 206.

at length other tubes are produced on the transverse plates, thus filling up the intervals, and constituting a uniform tubular mass; the surface being covered with a green fleshy substance, beset with stellular animalcules. The protruded polype of another beautiful species of Tubipore (*Tubipora rubeola*) is represented magnified, *Pl.* 6, *fig.* 4; and a view of an expanded polype of the same seen from above, in *fig.* 6; the polype of another species of Tubipore is represented in *fig.* 12.

26. GEOGRAPHICAL DISTRIBUTION OF CORALS.—Having described a few of the principal varieties of the Polypifera, I will next consider the geographical distribution of these zoophytes; and subsequently review the important physical changes effected by creatures so minute, and apparently so incompetent to produce any material alteration in the earth's surface.

The Corals are inhabitants of the ocean; many species prefer the immediate influence of atmospheric changes, and are seen on the rocks and plants left bare by the reflux of the tide, sometimes in such profusion that the whole surface appears one animated mass. At the period of the great equinoctial tides, when the sea retires from the rocks which it has overflowed for many preceding months, the Polypifera, when the waters first recede, are full of vigour, but languish as they lose their moisture, and perish if they remain long uncovered by the sea.

Some kinds are situated on the southern slope of the rocks; others, on the contrary, are attached to the opposite aspect, and never to the former. The larger forms are rarely found in places exposed to violent currents; it is in the hollows of the rocks, in submarine grottos, in the shelter of large and solid masses, that these species attach themselves. Many appear fitted to enjoy the powerful action of the surges, their pliant branches bending to the movements of the waves, and floating in the agitated water; while others

form immoveable rocks, which increase slowly but surely, until they become elevated above the surface of the waters, and constitute reefs and islands, as I shall hereafter describe.

The distribution of the Anthozoa is not solely regulated by the relative depths of the water; like plants, they vary with the climate, and in cold latitudes the *Alcyonaria* and some *Hydroida* are alone to be met with. On the coasts of Britain, between 50° and 60° of north latitude, only one or two minute stony corals represent, with the common *Actinia*, multitudinous in its individuals and varieties, and a few allied but rarer genera, the *Actinoidea;* whilst the two other groups present many forms. As we proceed southwards the numbers of each group increase; it is not, however, before the 34th degree of northern latitude that the Corals become developed to the grandeur and importance which they afterwards attain, to the extent of a parallel southern latitude, except, in the waters of the Atlantic, around the Bermuda Islands, where corals abound, owing to the temperature induced by the influence of the Gulf-stream.* It is therefore within the tropics, in a zone of more than 60 degrees expansion, that these beings, scarcely visible to the naked eye, hold their empire in a medium whose temperature knows no change; and from the depths of the ocean elevate those immense reefs that may hereafter form a communication between the inhabitants of the temperate zones.†

* Mr. Dana states that 60° Fahrenheit limits the growth of Corals. Corals occur, however, at the Bermudas, which are in lat. 33°, four or five degrees beyond the Coral-limits, because of the increased temperature of the water occasioned by the Gulf-stream; on the other hand, there are no Coral-reefs around the Galapagos Islands, which are situated under the equator, because of the cold waters of the southern current up the South-American coast, by which the temperature of the ocean is reduced to 60°, though 20° further to the west the waters are at 84°. (See Mr. Dana on "Areas of Subsidence in the Pacific Ocean," American Journal of Science, vol. xlv. p. 131.)

† For detailed remarks on the geographical distribution of the Coral-

The Sponges are similarly prolific to a vast extent, presenting enormous masses and fantastic shapes, in the Mediterranean and tropical seas; whilst a stunted and limited, though still varied and numerous, group of Spongiadæ grow around the coasts of the temperate and colder seas. The Sponges frequent the fresh waters also; and the study of the growth and structure of the *Spongilla* has enabled naturalists of late to add much to our knowledge of these low forms of life.

27. APPEARANCE OF THE LIVING CORALS. — In some parts of the sea the eye perceives nothing but a bright sandy plain at the bottom, extending for many hundred miles; but in the Red Sea, the whole bed of this extensive basin of water is absolutely a forest of submarine plants and zoophytes. Here are bryozoa and sponges, sertulariæ, gorgoniæ, madrepores, fungiæ, and other anthozoa, with fuci, algæ, corallines, and all the variety of marine vegetation, covering every part of the bottom, and presenting the appearance of a submarine garden of the most exquisite verdure, enamelled with animal forms, resembling, and even surpassing in splendid and gorgeous colouring, the parterres of the East.

Ehrenberg, the distinguished German naturalist, who has laboured so assiduously and successfully with pen and pencil in illustrating the natural history of the Infusoria and Foraminifera, was so struck with the magnificent spectacle presented by the living Corals in the Red Sea, that he exclaimed with enthusiasm, "Where is the paradise of flowers that can rival in variety and beauty these living wonders of the

larian Zoophytes, the reader is referred to the works of Lamouroux, Blainville, Dana, Darwin, and others. With regard to the Bryozoan Zoophytes, an excellent synopsis of their distribution in depth, according to the marine zones, on the British coast, may be seen in Mr. Alder's "Catalogue of the Zoophytes of Northumberland and Durham," Trans. Tyneside Nat. Field-club, vol. ii. p. 98, and in the Microscop. Journal, 1857, p. 242. To Mr. Allman's beautiful monograph of the Fresh-water Bryozoans (Ray Society, 1856) we have already referred.

ocean?" Some have compared the appearance to beds of tulips or dahlias; and, in truth, the large fungiæ, with their crimson disks and their purple and yellow tentacula, bear no slight resemblance to the latter.

The impressions produced upon first seeing a grove of live Corals are thus vividly portrayed by Mr. Jukes.*—

"In a small bight of the inner edge of this reef was a sheltered nook, where the extreme slope was well exposed, and where every coral was in full life and luxuriance. Smooth round masses of mæandrina and astræa were contrasted with delicate leaf-like and cup-shaped expansions of explanaria, and with an infinite variety of branching madreporæ and seriatoporæ, some with mere finger-shaped projections, others with large branching stems, and others again exhibiting an elegant assemblage of interlacing twigs, of the most delicate and exquisite workmanship. Their colours were unrivalled,—vivid greens, contrasting with more sober browns and yellows, mixed with rich shades of purple, from pale pink to deep blue. Bright red, yellow, and peach-coloured nulliporæ clothed those fleshy masses that were dead, mingled with beautiful pearly flakes of eschara and retipora; the latter looking like lace-work in ivory. In among the branches of the corals, like birds among trees, floated many beautiful fish, radiant with metallic greens or crimsons, or fantastically banded with black and yellow stripes. Patches of clear white sand were seen here and there for the floor, with dark hollows and recesses, beneath overhanging masses and ledges. All these, seen through the clear crystal water, the ripple of which gave motion and quick play of light and shadow to the whole, formed a scene of the rarest beauty, and left nothing to be desired by the eye, either in elegance of form or brilliancy and harmony of colouring."

The vast abundance and variety of animal life in these Coral formations is thus vividly depicted by the same naturalist:—

"A block of coral-rock, that was brought up by a fish-hook from the bottom of one of our anchorages, had its surface covered with brown, crimson, and yellow nulliporæ, many small actiniæ, and soft-branching corallines, sheets of flustra and eschara, and delicate retiporæ, looking like beautiful lace-work carved in ivory. There were several small sponges and alcyonia, sea-weeds of two or three species, two species of

* "Narrative of the Surveying Voyage of H. M. S. *Fly*, in 1842—1846;" by J. B. Jukes, Naturalist to the Expedition, vol. i. p. 117.

comatula, and one of ophiura, of the most delicate colours and markings, and many small, flat, round corals, something like nummulites in external appearance. On breaking into the block, boring shells of several species were found buried in it: tubes formed by annelida pierced it in all directions, many still containing their inhabitants: while two or three worms, or nereis, lay twisted in and out among its hollows and recesses; in which likewise were three small species of crabs. This block was not above a foot in diameter, and was a perfect museum in itself, while its outside glared with beauty from the many brightly and variously coloured animals and plants. It was by no means a solitary instance; every block that could be procured from the bottom in from 10 to 20 fathoms was like it. What an inconceivable amount of animal life must be here scattered over the bottom of the sea, to say nothing of that moving through its waters; and this through spaces of hundreds and hundreds of miles! Every corner and crevice, every point occupied by living beings, which, as they become more minute, increase in tenfold abundance." *Ibid.* vol. i. p. 17.

28. CORAL-REEFS.—The vast accumulations of calcareous rocks in tropical seas, resulting from the consolidation of the disintegrated skeletons of polypifera, have already been alluded to, but the physical changes that are produced by such apparently inadequate means require further consideration, since they illustrate the formation of the coralline rocks of the secondary and palæozoic epochs.

Mr. Juke's description, above quoted, of a composite block of Coral illustrates this point; and in the little *Flustræ* of our coast (p. 612), delicate and brittle though they be, we perceive the elements of those important changes to which the large lamellar corals of tropical seas are giving rise. In the specimen before us, you may observe that the base of the mass of a *Flustra foliacea*, which is about six inches in diameter, is already consolidated by an aggregation of sand, that has filled up the interstices. On the surface are numerous parasitical shells and Corals, and between the convolutions of its foliated expansions, echini, crustacea, and other animals have taken shelter; while sand and mud have invested every cranny of the lower third of the specimen, and imbedded serpulæ, sabellæ, and fragments of many

species of shells. It is evident that, were the whole specimen filled up and surrounded by detritus, as it shortly would be at the bottom of the sea, a solid block would be formed, exhibiting, when broken, the remains of the Flustra, impacted in a conglomerate of sand, shells, and zoophytes. Thus we perceive that even the delicate, friable skeletons of the Flustræ of our shores may become the nucleus of a solid rock; and in the process described, we have, as it were in miniature, the formation of a Coral-reef.*

28.* CORAL-REEF OF LOO CHOO.—But it is in tropical seas that the *Mæandrinæ*, *Astrææ*, *Caryophylliæ*, and other stony Corals form those immense masses, which not only give rise to groups of islands in the bosom of the ocean, but are gradually forming tracts of such extent that a new continent may spring up where the fabled Atalantis is supposed to have once flourished. From the many interesting descriptions of the nature and formation of Coral-reefs and islands that have been published by our voyagers, I select the following account, by Captain Basil Hall, of a Coral-reef near the great island of Loo Choo:—

"When the tide has left the rock for some time dry, it appears to be a compact mass, exceedingly hard and rugged: but as the water rises, and the waves begin to wash over it, the polypes protrude themselves from holes which were before invisible. These animals are of a great variety of shapes and sizes, and in such prodigious numbers, that in a short time the whole surface of the rock appears to be alive and in motion. The most common form is that of a star, with arms or tentacula, which are moved about with a rapid motion in all directions, probably to catch food. Others are so sluggish that they may be mistaken for pieces of the rock and are generally of a dark colour. When the coral is broken above high-water mark, it is a solid, hard stone; but, if any part of it be detached at a spot where the tide reaches every day, it is found

* Some reefs are nearly wholly composed of Serpulæ and Serpuloid shells; others of Nullipores and similar calciferous sea-plants; and in all reefs the Bryozoa supply much material, though seldom found in such masses as in the Crag, and in the Maestricht and Faxoe Chalk.

to be full of polypes of different lengths and colours; some being as fine as a thread, of a bright yellow, and sometimes of a blue colour. The growth of coral appears to cease when no longer exposed to the washing of the sea. Thus a reef rises in the form of a cauliflower, until the top has gained the level of the highest tides, above which the animalcules have no power to advance, and the reef of course no longer extends upwards."

29. CORAL-ISLANDS.—Kotzebue, Flinders, Quoi and Gaimard, Darwin, Dana, Jukes, and others have severally described the formation of Coral-islands; the following is an abstract of their observations:—

The coral-banks are everywhere seen in different stages of progress: some are become islands, but not yet habitable; others are above high-water mark, but destitute of vegetation; while many are overflowed with every returning tide. When the polypes of the corals at the bottom of the ocean cease to live, their skeletons* still adhere to each other; and, the interstices being gradually filled up with sand and broken pieces of corals and shells, washed in by the sea, a mass of rock is at length formed. Future races of these animalcules spread out upon the rising bank, and in their turn die, and thus increase and elevate this wonderful monument of their existence.

The reefs which raise themselves above the level of the sea are usually of a circular or oval form, and surrounded by a deep and oftentimes unfathomable ocean. In the centre of each, there is generally a shallow lagoon with still water, where the smaller and more delicate kinds of zoophytes find a tranquil abode; while the stronger species live on the outer margin of the isle, where the surf dashes over them. When the reef is dry at low water, the coral-animals cease to increase. A continuous mass of solid stone is then seen, composed of shells, echinoderms, and fragments of corals, united by calcareous sand, produced by the pulverization of the shells and of the friable polyparia. Fragments of coral-limestone are thrown up by the waves; these are cracked by the heat of the sun, washed to pieces by the surge, and drifted on the reef. After

* The chemical constitution of the polyparies of Alcyonarian and Actinoidean Corals is treated of by Prof. Dana in his "Zoophytes," p. 56, and by Prof. B. Silliman, jun., in the Appendix to that work. Mr. B. Silliman has shown, contrary to expectation, that they contain a much larger proportion of fluorine than of phosphoric acid.

this the calcareous mass is undisturbed, and offers to the seeds of the cocoa, pandanus, and other trees and plants, floated thither by the waves, a soil on which they rapidly grow, and overshadow the white dazzling surface. Trunks of trees, drifted by currents from other countries, find here at length a resting-place, and bring with them some small animals, as lizards, insects, &c. Even before the trees form groves or forests, sea-birds nestle there, and strayed land-birds find refuge; and at a still later period, Man takes possession of the newly-created country. It is in this manner that the Polynesian Archipelago has been formed.*

The immediate foundations of these islands are ancient coral-reefs, and some of these, in all probability, are based on the cones or craters of submarine volcanos long since extinct; and others on the lofty peaks of a submerged continent which has undergone a slow subsidence, and thus admitted of the growth of successive generations of the coral-secreting zoophytes, and the formation of immense beds and zones of submarine coral-rocks. There is another circumstance worthy of remark: most of these islands have an inlet through the reef† opposite to the large valleys of the neighbouring land, whence numerous streams issue and flow into the sea; an easy ingress is thus afforded to vessels, and the means of obtaining an abundant supply of fresh water readily offered.

Of the immense extent of the changes here contemplated we may form some idea from the facts stated by competent observers, that in the Indian Ocean, to the south-west of Malabar, there is a chain of reefs and islets 480 geographical miles in length; on the east coast of New Holland, an unbroken reef 350 miles long; between that and New Guinea, a Coral-formation which extends upwards of 700 miles; and that Disappointment Islands and Duff's Group are connected by 600 miles of Coral-reefs, over which the natives can travel from one island to another.

30. Formation of Coral-islands.—From the grand scale on which these operations have been carried on in the Pacific, and the powerful volcanic action of which those latitudes have been the theatre, as shown by the elevatory

* At least so much of it as can be truly said to be of late origin. Some of the islands, on the other hand, are probably the coral-crested *sinking* peaks of a mountainous and possibly once continental area.

† Analogous to the broken side of a crater.

movements to which the neighbouring continents have been subjected, the extremely small extent of dry land in that world of waters is a very striking phenomenon. This remarkable fact was supposed by Sir C. Lyell* to admit of explanation, on the supposition that a gradual subsidence had been going on for ages over a vast area of the bed of the Pacific, which occasioned the solid materials produced by the Coral-zoophytes to sink down beneath the waters, and therefore no considerable additions were made to the dry land above the level of the sea: the Polynesian Archipelago and the submerged Coral-reefs alone indicating the stupendous changes effected by zoophytal agency. This opinion has been confirmed by the observations of Mr. Darwin, whose explanation of the mode in which the formation of Coral-islands takes place is a beautiful example of philosophical induction.

The coral-reefs are described by Mr. Darwin as of three distinct kinds, arising from the different circumstances attending their production. First, *Atolls;*† secondly, *barrier-reefs*, which are ridges of coral either extending in straight lines in front of the shores of a continent or large island, or encircling a group of small islands, and separated from the land by a deep channel of water; thirdly, *fringing-reefs*, or banks of coral superimposed on the slopes of the adjacent land, and at no great distance from the shore.

By the gradual subsidence of the land, and the coincident upward growth of the corals, fringing-reefs are gradually converted into barrier-reefs, and the latter into Atolls. Hence it is inferred, that coasts merely fringed by reefs have not subsided to any considerable amount, but either have remained stationary, or have been upheaved, since the growth of the coral. When a barrier-reef, encircling an island, gradually sinks down, the corals go on growing vigorously upwards; but, as the island sinks, the water gains inch by inch on the shore, and the mountain-tops at length become separate islands, within one great reef; and ultimately the highest pinnacle disappears, and a perfect Atoll is formed. Hence lagoon-islands, having originated from encircling barrier-reefs, resemble them in

* Principles of Geology, 1st edition.

† The circular or lagoon islands are so called by the natives.

general size and form, and in the manner in which they are grouped together; and they may be regarded as outline-charts or models of the sunken islands they now surmount. By this theory of the upward growth of polypifera during the subsidence of the land on which they are based, Mr. Darwin satisfactorily explains all the leading phenomena of those marvellous structures, the barrier-reefs, and of those fairy coral-islands that begem the vast expanse of the Pacific, and flourish in the midst of its mighty billows. The narrow belt of land of these insular zones, frequently but a few hundred yards wide, is surrounded by a deep and often unfathomable ocean, and encloses a lake of tranquil water; it is crowned with cocoa-nut trees, clothed with a luxuriant tropical vegetation, and begirt with a beach of glittering sand, on which are constantly dashing the snow-white breakers of the azure sea. Nowhere, as Mr. Darwin beautifully remarks, can be found such wonderful proofs of the power of vitality to repel the influence of mechanical force; for the breakers far exceed in violence those of our temperate regions, and it is impossible to behold them without feeling a conviction, that rocks of quartz or granite would speedily be demolished by such irresistible agents;* and yet there stand, immoveable, those marvellous monuments—

"Raised by the feeblest creatures in existence,"

unscathed by the raging billows, and smiling with perpetual verdure,—the oases of that vast wilderness of waters! †

31. MONTGOMERY ON CORAL-ISLANDS. — The formation of islands and continents by the vital energies of countless myriads of minute beings, the unconscious living instruments of stupendous physical changes, is invested with so much of the sublime and the marvellous, as to form a subject alike calculated to engage the attention of the philosopher and to excite the imagination of the poet; and I am tempted to relieve this detail with the following beautiful lines by James Montgomery:‡—

* See Mr. Darwin's delightful volume, "On the Structure and Distribution of Coral Reefs."

† The striking isolation of these tiny specks of land on the vast expanse of ocean can be best realized by a survey of Mr. Wyld's great Model of the Earth.

‡ From "The Pelican Island," by James Montgomery.

"I saw the living pile ascend,
The mausoleum of its architects,
Still dying upwards as their labours closed
Slime the materials, but the slime was turned
To adamant by their petrific touch.
Frail were their frames, ephemeral their lives,
Their masonry imperishable. All
Life's needful functions, food, exertion, rest,
By nice economy of Providence,
Were overruled to carry on the process,
Which out of water brought forth solid rock.
Atom by atom, thus the mountain grew
A Coral-island, stretching east and west;
Steep were the flanks with precipices sharp,
Descending to their base in ocean-gloom.
Chasms few, and narrow, and irregular,
Form'd harbours, safe at once and perilous;
Safe for defence, but perilous to enter.
A sea-lake shone amidst the fossil Isle,
Reflecting in a ring its cliffs and caverns,
With heaven itself seen like a lake below.
Compared with this amazing edifice,
Raised by the feeblest creatures in existence,
What are the works of intellectual man,
His temples, palaces, and sepulchres?
Dust in the balance, atoms in the gale,
Compared with these achievements in the deep,
Were all the monuments of olden time!
Egypt's grey piles of hieroglyphic grandeur,
That have survived the language which they speak,
Preserving its dead emblems to the eye,
Yet hiding from the mind what these reveal;
Her Pyramids would be mere pinnacles,
Her giant statues, wrought from rocks of granite,
But puny ornaments for such a pile
As this stupendous mound of catacombs,
Fill'd with dry mummies of the builders, worms!"

32. FOSSIL ZOOPHYTES.—The conditions under which corals and other zoophytes are preserved in the mineral kingdom, and the formation of conglomerates from the debris

of corals and shells, have been described in the previous lectures; in this place I shall offer a cursory review of the geological distribution of fossil zoophytes, without entering upon details which will be found more or less fully exemplified in the account of the organic remains of the respective systems of deposits.

The coral-limestones now forming on the shores of the Bermuda and Bahama Islands (see p. 83), and similar conglomerates on those of the Isle of Ascension (p. 89), prove that at the present time accumulations of calcareous stone are going on analogous in character to many of the fossiliferous deposits of the Chalk, Oolite, and other ancient formations. Mr. Darwin has observed a similar effect in the Pacific, where disintegrated coral-reefs give rise to vast deposits of calcareous detritus, which, when dry, closely resembles soft chalk. In the West Indies, blocks of silicified mæandrinæ, astrææ, and other reef-forming species are abundantly distributed in the superficial alluvium of Antigua and other islands. The pliocene, or newer tertiary of Palermo, abounds in corals,* some of which belong to species that still inhabit the Mediterranean. In the Crag, there are a few species of extinct corals,† with many forms of Bryozoa, chiefly now unknown as natives of the adjacent seas. The miocene of North America contain many kinds of zoophytes, some of which appear to be peculiar to those strata.‡ In the eocene deposits there are several extinct genera and many species. Excepting four genera in the Crag,§ we have in England no fossil corals of younger age

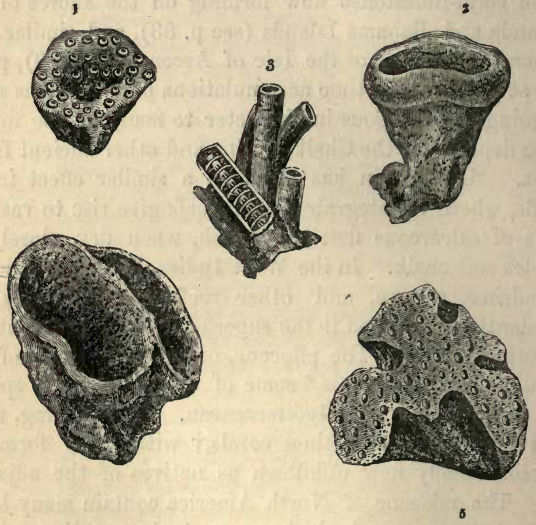
* Michelotti, *Spec. Zoophyt. Diluv.*, and Michelin, *Iconographie Zoophytologique*, have figured and described many of these.

† See Edwards and Haime's Monograph of Brit. Foss. Corals, Palæont. Soc. 1850

‡ See report on Corals from the Tertiary Formations of North America, by Mr. Lonsdale; Geol. Soc. Journal, vol. i. p. 495.

§ And a Millepore in the Pleistocene beds of Ayrshire.

than those of the Bracklesham and London clays of eocene age.* It is interesting, however, to observe that the miocene tertiaries of Austria contain reefs both of true coral sand of the vegetable corallines (Nullipores); the former proving that in tertiary times the Vienna basin was a continuous sea with the present area of the Red Sea, the nearest



LIGN. 146.—FOSSIL ZOOPHYTES; FROM FARRINGDON, BERKS.

Fig. 1. *Manon peziza.* 3. *Verticillipora anastomosans.*
2 and 4. *Manon.* 5. *Tragos?*

point where such corals are now found, and which was probably a portion of the channel of some old north-going current of warm water, like the existing Gulf-stream.† In the Chalk-formation of England corals ‡ are not abundant; throughout vast areas of the fine white chalk there are no considerable beds of corals, nor appearance of coral-reefs; the species

* Edwards and Haime, *loc. cit.* † Unger, Proceed. Vienna Acad. 1856.
‡ Edwards and Haime, *op. cit.* p. 44.

for the most part small and delicate (p. 330). There are, however, numerous genera and species of the bryozoa and sponges in the chalk and its associated beds.

The manner in which the remains of polypifera are distributed in our white chalk involves an interesting inquiry; they occur promiscuously intermingled with shells, echini, and fishes; we find no beds of corals—nothing to point out the former existence of reefs. This phenomenon, however, is in accordance with the general lithological character of the Chalk-formation, and the nature of its organic remains; both of which indicate a profound ocean. As polypifera can only exist at moderate depths, the occurrence of coral-reefs was not to be expected, except in those areas which may be supposed to have been formed in the shallows, or near the sea-shores.

The cretaceous coral-reefs evidently existed further south, for the Hippurite-limestone of the south of Europe and the Gosau-chalk of the Eastern Alps abound with corals.* Corals are not uncommon also in the Maestricht chalk.

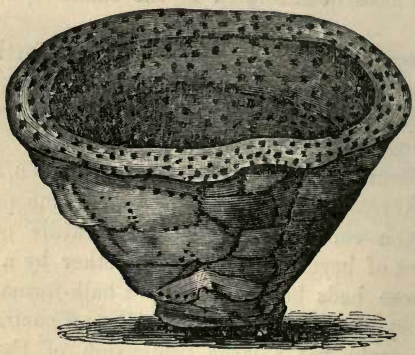
In the Danish islands of Seeland and Möen, the flinty chalk is covered by bryozoan limestone, some portions of which form a compact building-stone, while others are mere masses of bryozoa cemented together by a white detritus. These beds belong to the Chalk-formation; for, although they abound in univalve shells not common in our cretaceous strata, yet a large proportion of the sponges, bryozoa, echinites, and belemnites are identical with those of the English Chalk. Sir C. Lyell therefore infers, "that the peculiarity of the fossil fauna of Faxoe † was produced more by geographical conditions, such, for example, as the

* Michelin, Icon. Zoophyt. plates 64 to 73; and Reuss, Trans. Vienna Acad. vol. vii.

† A locality in Denmark, where these deposits are best displayed. See Geol. Trans. 2nd ser. vol. v. p. 243.

local shallowness of that part of the cretaceous sea, than by any general change in the creatures inhabiting the ocean, effected in the period that may have intervened between the formation of the White Chalk and the Faxoe limestone." The same may be said of the bryozoiferous strata at Maestricht, which contain also numerous nullipores.

The remains of sponges are very frequent in the chalk,* and in many places not only do they swarm in the limestone, but also in the flints; so that almost every nodule encloses a sponge or other poriferous zoophyte. The Upper Greensand in some localities contains immense numbers of porifera.† The gravel-pits, as they are called, in the neighbourhood of Farringdon,‡ in Berkshire, are extremely pro-



LION. 147.—FOSSIL ZOOPHYTE FROM THE UPPER OOLITE AT CAEN.

(Chenendopora fungiformis, Lamouroux.)

lific in fossils of this kind. These beds consist of a coarse

* Michelin, *Icon. Zooph.* plates 28 to 42.

† Miss Benett's *Catal. Wiltshire Fossils*, 4to, 1816.

‡ See Mr. Austen's Memoir on the Fossiliferous Sands and Gravels of Farringdon, Quart. Journ. Geol. Soc. vol. vi. p. 464; and Mr. D. Sharpe's Memoir on the same subject, *ibid.* vol. x. p. 176.

friable conglomerate, formed of sand, shells, bryozoa, sponges, echinoderms, and the debris of other marine animals, impregnated with iron; some layers of concretionary indurated masses occur, originating from infiltration of carbonate of lime.

They contain myriads of perfect shells and zoophytes; casts of nautili, water-worn and other fossils from the Oolites, belemnites, &c. The *Verticillipora anastomosans* * (*Lign.* 146, *fig.* 3) is a very elegant zoophyte often met with in this locality.

One of the most abundant and perfect of the sponge-like forms is a cyathiform zoophyte called "*Petrified salt-cellar*" by the quarrymen; it is of a porous structure, and the inner surface is covered with oscula, or little openings: it closely resembles the fossil sponge from Caen, figured in *Lign.* 147, which is said also to occur in the Upper Greensand at Warminster.

33. VENTRICULITES OF THE CHALK.—A very elegant and interesting family of Zoophytes, illustrated by me in an early memoir (published in the "Linnæan Transactions," vol. xi.), and subsequently named *Ventriculites*,† occurs in the chalk of Kent, Sussex, and Wiltshire in such numbers, and under such dissimilar forms, as to require a passing notice in this place. They abound in some parts of the chalk of Europe; and occur also in the jura-beds of Randen.

The original form of the Ventriculite was that of a funnel, or hollow inverted cone, terminating in a point at the base, whence numerous fibres proceed, by which it was attached to other bodies. The outer integument was reticulated, that is, disposed in meshes like net-work, and the inner surface was studded over with regular openings, the orifices of tubular cells, each of which was probably occupied by a polype. The substance of the polyparium, or frame-work, of this aggregation of animalcules, appears to have been analogous to that of the soft alcyonia,

* Much better figured by Mr. D. Sharpe *loc. cit.* p. 195, pl. 5, fig. 1

† Medals of Creation, vol. i. p. 242; and Mr. J. Toulmin Smith's papers on the Ventriculidæ of the Chalk, *Ann. Nat. Hist.* 2 Ser. vol. i. 1848.

and to have possessed a common irritability, and been able to expand and contract. This opinion is based on the circumstance, that some specimens occur in which the zoophyte is in the form of a nearly flat circular disk, and others in that of a subcylindrical pouch; in the former state the outer reticulated structure is elongated, while in the latter it is contracted and corrugated. The polype-cells are cylindrical and very regular; of these cells the flints often present beautiful casts which appear like rows of minute pillars on the inner surface.

When the flint that fills up the cavity of a Ventriculite can be extracted, it is found to be a solid cone, having its surface studded over with papillæ, which are casts of the orifices of the polype-cells. When the enclosed polyparia in flint-nodules have perished, chalcedony and quartz-crystals, and sometimes crystallized pyrites, are found filling up more or less completely the cavities left by the decayed parts of the zoophyte.*

34. ZOOPHYTES OF THE JURASSIC FORMATION.—The Oolite, as we have previously remarked, abounds in corals, and contains beds of limestone which are merely coral-reefs that have undergone no change but that of elevation from the bottom of the deep, and the consolidation of their materials. The Coral-rag of Wilts presents in fact all the characters of modern reefs; the polypifera belong chiefly to the *Astræidæ*, the genera of which family principally contribute to the formations now going on in the Pacific. Shells, echinoderms, teeth and bones of fishes, and other marine exuviæ, occupy the interstices between the corals, and the whole is consolidated by sand and gravel, held together in some instances by calcareous, in others by silicious, infiltrations. In the chert of the Portland Oolite at Tisbury, Wiltshire, masses of a beautiful silicified coral occur; the polished

* I beg to refer to my paper on a "Microscopical Examination of Chalk and Flint," published in Ann. Nat. Hist. 1845, vol. xvi. p. 73 for a particular account of the silicification of these and other zoophytes. See also above, p. 308.

† Edwards and Haime, *loc. cit.* p. 75.

section of a fragment is shown in *Lign.* 148, *fig.* 9. Large masses of a cellular coral abound in the limestones of the Great Oolite (*Calamophyllia radiata*). The corals, shells, &c., are of extinct species. Those who have visited districts where the Coral-rag forms the immediate sub-soil, and is exposed to view in the quarries, or in natural sections, must have been struck with the resemblance of these rocks to modern coral-banks. We know that in our present seas all situations and circumstances are not alike favourable to the existence and growth of polypifera; in some parts of the ocean they abound, and in others are altogether wanting. In like manner, in the deposits of the Jurassic formation, which extend over a great part of Europe, and have been formed in a sea of vast extent, beds of coral are not universally distributed, but occur only in certain districts (Nuttheim, for instance); in other words, they occupy the situations which in their native seas presented the conditions required by their peculiar organization.

The Lias contains but very few polypifera; *Isastræa Murchisoni* occurs in the lias of Skye. The Trias only a small number (in the Muschelkalk and Halstadt lime-stone).

35. Corals of the Palæozoic Formations. — The Mountain-limestone of the Carboniferous system, which will come under our notice in the next discourse, abounds in the cellular and lamelliferous zoophytes:* and many of the deposits of the Devonian and Silurian system teem with anthozoan corals,† of peculiar forms, and typical of particular groups of strata. The corals of the Silurian deposits of England ‡ equally prevail in the corresponding strata of North America.§

* Edwards and Haime, Monog. Brit. Foss. Corals, 1852.

† Edwards and Haime, *ibid.* 1853 and 1854; and Ann. des Sc. N. 1848.

‡ Murchison's "Silurian System," vol. ii., and "Siluria," pp. 119 and 212, &c. See also M' Coy's Palæoz. Foss. Cambridge, plates 1 B and 1 C.

§ See Hitchcock's "Geology of Massachusetts," and Hall's "Palæontology of the State of New York."

This wide geographical range of the same types of coral-zoophytes seems to indicate a more equal temperature in the

LIGN. 118.—FOSSIL CORALS.*

1, 3. Cyphyma subturbinata; Wenlock limestone; Dudley.
2. Palæocyclus (one of the *Fungidæ*); Dudley.
4. Cyathophyllum hexagonum; Devonshire.
5. Syringopora geniculata; Mountain-limestone; Mendip Hills.
6. Thecosmilia annularis; Coral-rag; Wilts.
7. Lithostrotion basaltiforme; Mountain-limestone; Yorkshire.
8. Slice of Isastræa oblonga; Portland Oolite; Wilts.
9. Slice of Coral-marble (Cyathophyllum); Devonshire.

seas of those remote epochs than at present prevails; for

* For numerous illustrations of Fossil Corals, Sponges, and other Zoophytes, see Pictorial Atlas of Fossil Remains, plates xxxiv. to xlv.

the reef-forming genera do not now exist in waters of a temperature under 60°, and are therefore, with the exception of the Bermudas (p. 633), restricted to intertropical regions.

The simple turbinated corals, consisting, like the Fungia and Turbinolia (*Pl.* VI. *figs.* 8 and 15), of a solitary cell (*Lign.* 148, *figs.* 1, 2, 3), are found in great abundance and perfection in the Silurian limestones of Dudley, Wenlock, &c.; and are associated with numerous large composite corals, branched and massive.* The Wenlock limestone (in Norway, Sweden, Russia, and North America, as well as in Britain) contains a genus of singular beauty, and which, from the appearance presented by cross sections, is known by the name of *Chain-coral* (*Halysites catenularius; Lign.* 150, *fig.* 3). The tubes of this coral being oval in section, and arranged perpendicularly side by side in undulating lines, display in the transverse sections elegant markings resembling the anastomosings of delicate chains.

The fossil compound polypifera termed Lithostrotion † and Syringopora, consisting of clusters of parallel tubes, laterally united, form continuous layers, or reefs, in the Mountain-limestone of Ireland and other countries; and on the weathered surface of the stone, the corals stand out in relief as sharp as in the coral-rocks of a recent lagoon.

It is interesting to remark, with respect to fossil corals, that a certain peculiarity of structure distinguishes those of the palæozic formations from the secondary, tertiary, and existing corals. In Mr. Milne Edwards's classification ‡ of the corals proper, or *Zoantharia*, there are four chief orders, of which the *Z. aporosa* and *Z. perforata* belong to the recent Tertiary and Secondary periods; the *Z. tabulata* and *Z. rugosa* being chiefly characteristic of the palæozoic period. In the first two, or neozoic, groups of corals, the *septa*, or vertical plates attached to the inner sides of the cell, are essentially composed of six elements, "being disposed in

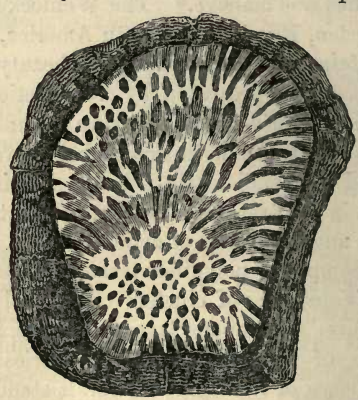
* See "Medals," chap. viii., for figures and descriptions of fossil corals; and Dr. Carpenter's "Microscope," chap. xi., for the structure of recent zoophytes.

† *Lithodendron*, "Medals of Creation," *Lign.* 70, pp. 260 and 264.

‡ Monograph (Pal. Soc.) 1850, p. x.

groups corresponding to the six primitive radii, or to a multiple of that number;" the third order (*Z. tabulata*), in which the septal apparatus is arranged as in the foregoing, but very rudimentary, includes two recent genera (*Millepora* and *Heliopora*), two tertiary, and four palæozoic genera; whilst the *Z. rugosa* has a *quaternary* arrangement of the septal plates, and is wholly palæozoic.

36. CORALLINE MARBLES.—Certain limestones, largely composed of corals, in which the interstices have been filled up by calcareous spar, and the enclosed zoophytes more or

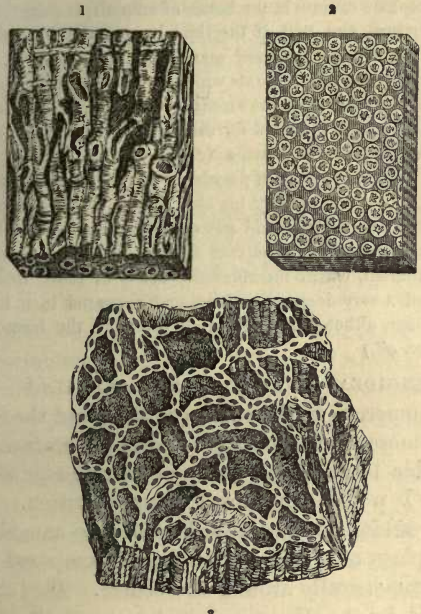


LIGN. 149.—SECTION OF FAVOSITES POLYMORPHA;* IN A POLISHED PEBBLE, FROM TORQUAY.

less transmuted into the same substance, are susceptible of a high polish, and constitute some of the most beautiful of marbles. The elegantly figured limestones of Babbicombe and Torquay in Devonshire, and those of Clifton in Derbyshire, owe their markings to the petrified zoophytes of which they are in a great measure made up. The black marbles of Kilkenny and Belgium are mottled with varied and elegant figures of the purest white, which are sections of corals and shells transmuted into calcareous spar.

* Drawn by Miss Jane Allnutt from a beautiful specimen in the possession of Mrs. Allnutt, of Clapham Park.

Many of the pebbles thrown up by the waves on the shore along the coast of Devonshire are water-worn fragments of the coral-limestones of that country, and, when cut and polished, display exquisite sections of the enclosed corals (*Lign.* 149).*



LIGN. 150.—CORALLINE MARBLES.

Fig. 1. Silurian limestone, composed of *Syringopora bifurcata*; Dudley.
— 2. Polished section of a marble formed of *Lithostrotion irregulare*; Derbyshire. (Mountain-limestone.)
— 3. Chain-Coral *(Halysites catenularius)*; Dudley (Silurian.)

A reddish marble, beautifully marked by the sections of the enclosed coral-tubes ("corallites"), and susceptible of a

* The form and structure of the species of coral of which a section appears in this polished pebble are shown in *Lign.* 86, Medals of Creation, vol. i. p. 258.

good polish, is quarried in some parts of Westmoreland and Derbyshire (*Lign.* 150, *fig.* 2). Mr. Parkinson * ascertained that the hue of this marble may be dependent on the original colour of the coral, which probably was of a reddish hue.

I have mentioned (p. 617), that the earthy matter of the recent corals, like the phosphate of lime in the bones of animals, is secreted by a membranous structure, and that, if the lime be removed by a chemical process, the tissue will be rendered manifest. Few, however, will be prepared to learn, that even in corals which have been entombed in the solid rock for innumerable ages the animal membrane can be detected. To Mr. Parkinson we are indebted for the knowledge of this interesting fact. He immersed a piece of marble (*Lign.* 150, *fig.* 2) in dilute muriatic acid, which has the property of dissolving calcareous earth without affecting animal matter: to employ his own words, "as the calcareous earth dissolved, and the carbonic acid gas escaped, I was much pleased to observe the membranaceous substance appear, depending from the marble in light, flocculent, elastic membranes. Many of these, most unexpectedly, retained a very deep red colour, and appeared in a beautiful and distinct manner, although not absolutely retaining the form of the tubipore." (*Loc. cit.*)

37. CRINOIDEA, OR LILY-SHAPED ANIMALS.†—The Echinites, so numerous in the chalk (p. 338), and the Star-fishes, which are more sparingly distributed in the cretaceous strata, are referable to the same group of marine animals as those to which I would now direct your attention. All these creatures belong to the class *Radiaria*, so named from the different parts of which the animal is composed being arranged symmetrically around the centre. This structure is exemplified in the *Uraster* and *Asterias*, or Cross-fish and Star-fish, that abound on our coasts, and must be familiar to every one. These animals have a central disk, containing the mouth and viscera, from which proceed five long arms or rays; the skeleton is composed of numerous little bones,

* Organic Remains of a Former World, vol. ii. p. 16, pl. I. *fig.* 3.

† Medals of Creation, chap. viii. The *Pictorial Atlas Foss. Rem.* contains numerous figures of Crinoidea (plates XLVI. to LII.). See Müller's elaborate description of *Pentacrinus Caput-medusæ*, &c., Berlin. Transact. 1841, p. 177, &c.

enveloped in a tough integument. These bones, or *ossicula*, are calcareous; and are in close apposition over the body, but are articulated together in regular series along the margins of the rays, which are therefore strong and flexible. A longitudinal furrow extends from the mouth to the extremity of each ray, the sides of which are perforated by alternating rows of pores, for the exsertion of tubular tentacula.

Some kinds of Echinoderms (the *Comatulæ*, or Feather-stars), instead of the five flat rays, have jointed arms, that proceed from a central cup-shaped calcareous base, and divide and subdivide into delicate jointed tentacula, the sides of which are fringed with rows of still smaller articulated pinnæ or processes.* Now, if we imagine a Comatula placed with its mouth upwards, and fixed on the top of a jointed stem by the centre of its dorsal surface (a condition actually existing in the young Comatulæ), we have the essential type of the Crinoideans, or Lily-shaped animals, so named from a fancied resemblance of some of the species when in a state of repose to a closed lily. This family is not abundant at the present day; its existing representatives are a few small species (with or without stalks), on the British and European coasts, a more numerous series of large Comatulæ in the tropical seas, and by the rare fixed crinoid (*Pentacrinus Caput-Medusæ*) inhabiting the seas around the West Indies. Of this elegant and scarce representative of the seas around the West Indies, and of this sole representative of the numerous crinoideans of the palæozoic ages, but five or six specimens have been brought to Europe.† It belongs to that subdivision in which the joints of the column are pentagonal, hence its generic name.‡

38. Structure of the Crinoidea.—From this recent example (*Lign.* 151), which does not essentially differ from

* The living British Star-fishes are beautifully figured in the late Professor E. Forbes's charming work, published by Van Voorst, 1841.

† Petrifactions and their Teachings, p. 77. ‡ Medals, p. 282.

the extinct forms, a more accurate knowledge of the structure of these curious animals has been obtained. The Crinoideans are characterized by having a root or process of attachment, by which they are fixed at the base to the rock,

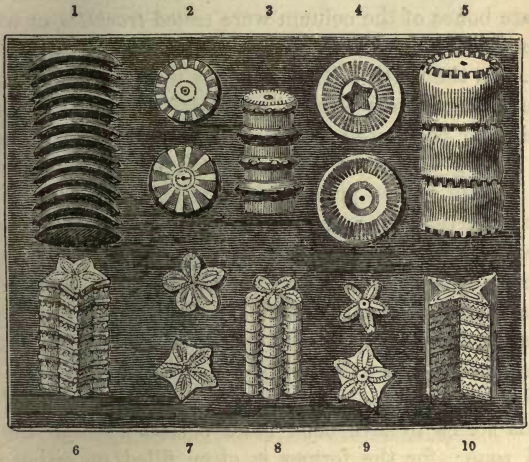
LIGN. 151.—THE BODY AND UPPER PART OF THE STEM OF PENTACRINUS CAPUT-MEDUSÆ.*

(From the West Indian Seas.)

—a stem composed of numerous articulations, or separate pieces of a solid calcareous substance,—and a cup or vase at the summit of the stem, which contains the body or viscera of the animal, and from the upper border of which proceed articulated arms or tentacula. When the animal is alive,

* First figured and described by M. Guettard; see Parkinson, Org. Rem. vol. ii. p. 266; and Müller, *op. cit.* p. 185.

the skeleton is covered by a soft integument, as in the Star-fishes; the mouth is situated on one side of the centre of the receptacle, which is surrounded by the arms that spread out and expand into a net to capture the living prey, and, like the tentacula of the hydra, seize and convey it to the mouth. I scarcely need remark that the Crinoidea are individual organisms, and are never aggregated and united by one common axis, as are the compound Polypifera that lately engaged our attention. There are some fossil crinoideans destitute of a stem, and these must have been free animals,



LIGN. 152.—STEMS OF ENCRINITES AND PENTACRINITES.

Fig. 1. Screw- or Pulley-stone; a cast in the hollow of an encrinital column.
2, 4. Articulating surfaces of different kinds of encrinital ossicula, or Trochites.
3, 5. Portions of encrinital stems, or Entrochi. 6, 8, 10. Stems of Pentacrinites.
7, 9. Separate ossicula, or Trochites, of Pentacrinites.

floating at liberty through the water, like their analogues, the recent Feather-stars.

The number of ossicula in the skeleton of a single Encrinite has been computed at thirty thousand; but in the more

complicated Pentacrinites they exceed one hundred and fifty thousand, and in the plumose species must amount to hundreds of thousands.* The detached ossicula occur in myriads in the Carboniferous, Devonian, and Silurian rocks, and the relics of one species alone sometimes form thick beds of marble in the mountain-limestone series.

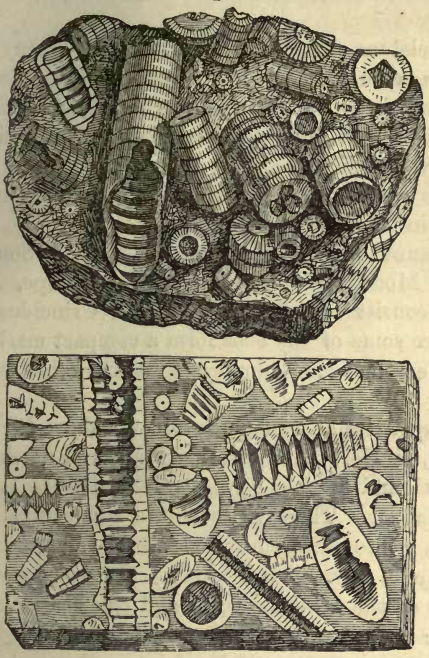
39. ENCRINITES AND PENTACRINITES.—The fossil remains of Crinoidea consist of the ossicula of the column, arms, and tentacula,—of the plates of the vase or receptacle,—and of the more massive peduncle, by which the base of the column was permanently fixed to the rock. The separate bones of the column were called *trochites*, or wheel-stones, by the early collectors; and several united, *entrochites*. In the north of England they were popularly known by the name of "fairy-stones," and "St. Cuthbert's beads:"† the circular perforated kinds are occasionally found in tumuli, having been worn as ornaments by the ancient Britons. These bodies present considerable variety in form, and their articulating surfaces are marked with diversified floriform and stellular figures; as in the series of specimens before us (*Lign.* 152). The central perforation, which is circular and very small in some species, and large and pentagonal in others, forms in the united column a channel from the receptacle to the base, which is supposed to have contained a chord of animal matter. The inner part of the ossicula seems to have been more perishable than the external zone; for the former is often filled up either with spar, or the material of the surrounding rocks. In the silicious veins and bands of chert that pervade some of the limestones of Derbyshire, the curious fossils termed "pulley-

* The ossicula of an Extracrinus are calculated, at a moderate computation, to amount to the number of nearly 750,000. Austin's *Monog. Crinoid.* p. 105.

† Parkinson (Org. Rem. vol. ii. p. 155, &c.) enumerates the popular names by which these little fossils have been known in different countries.

stones," or "screw-stones," often occur; these are casts formed by the infiltration of silex into the cavities of encrinital columns (*Lign.* 152, *fig.* 1).

1



2

LIGN. 153.—ENCRINITAL MARBLE OF YORKSHIRE.*

Fig. 1. Entrochites, or fragments of stems of Encrinites (*Rhodocrinus verus?*), lying in relief on a weathered block of limestone; from Garsdale, West Riding, Yorkshire.

2. Polished slab of the same encrinital marble, showing the portions of stems cut at various angles.

Occasionally encrinital joints are found in the fluor-spar

* For the Fossil Zoophytes and Crinoids of Yorkshire, see Prof. J. Phillips's "Geology of Yorkshire," especially vol. ii. plates 1, 2, and 3

contained in the mountain-limestone of Derbyshire;* and thus show that this beautiful spar has been the result of some metamorphic action on the limestone, the organic remains alone resisting the transmuting influence of the fluoric acid.

The skeletons of the Crinoidea, like the stony fabric of the corals, were, of course, secreted by the animal membrane; and, as in the fossil coral (p. 654), this tissue may be detected. Upon submitting some encrinital ossicula from the Derbyshire limestones to the action of weak acid, the calcareous earth was removed, and the original membrane appeared in transparent flocculi.†

40. DERBYSHIRE ENCRINITAL MARBLE.—Some of the strata of Mountain-limestone, both in Europe, Asia, and America, consist entirely of remains of Crinoidea; and in Derbyshire some of the beds form a compact marble, which is largely employed for chimney-pieces and other ornamental purposes.

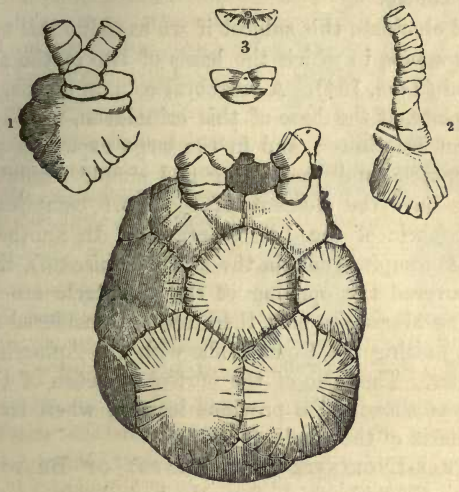
In the quarries on Middleton Moor, a short distance from Cromford, in Derbyshire, extensive quarries of this marble are worked, and abundance of these fossils are everywhere scattered about. The cavities of the entrochites are often filled with white calcareous spar, while the ground of the marble is of a dark reddish brown. In other varieties the substance of the fossils is white, and the ground dark-grey or brown: both kinds, when worked into polished slabs or ornaments, are very beautiful and interesting. A specimen of such limestone (from the borders of Westmoreland and Yorkshire), with the crinoidal columns in relief, is represented, *Lign.* 153, *fig.* 1, and a polished slab in *fig.* 2.

41. THE LILY-ENCRINITE.—One of the most elegant of the fossil crinoidea is the *Lily Encrinite* (*Encrinus liliiformis, Schlotheim*), which, as already stated, occurs only in the

* Quart. Journ. Geol. Soc. vol. vii. part 2, Miscell. p. 115.

† See Parkinson's Organic Remains, vol. ii. p. 166.

Muschelkalk of the Triassic system of Germany (p. 550), and is principally found in one locality, near the village of Erkerode, in Brunswick. The structure of this animal is beautifully exemplified in the fine specimen figured in *Lign.* 131, which was formerly in the collection of Mr. Parkinson *



LIGN. 154.—MARSUPITE † FROM THE CHALK, NEAR ARUNDEL.

(Collected and drawn by G. A. Coombe, Esq.)

Fig. 1. A plate with the base of one of the arms attached. 2. Lateral view of one of the arms. 3. The Ossicula, by which the arms are attached to the body. 4. The Marsupite, with the first five ossicula of two of the arms attached to the brim of the pelvis.

The stem of the *Encrinus liliiformis* is constructed of ossicula alternately large and orbicular, and small and

* Org. Rem. vol. ii. pl. XIV. p. 174.

† This is probably the *Marsupites lævigatus* of Forbes, *Dixon's Foss. Sussex*, pl. 20, fig. 8. The species of this genus have not, however, been yet well worked out. Remains of Marsupites have been found in the chalk of Kent (Margate), Sussex (Offham, Preston, Brighton, and Burpham, near Arundel), Wilts (Tidworth), and Danes Dike, Yorkshire.

cylindrical, thus forming a column of great flexibility. The "pelvis," or plated cup containing the body, resembles in shape a depressed vase; the upper part of its cavity appears to have been closed by an integument protected by numerous plates, the mouth of the animal being situated near the centre.

It will elucidate this subject if we examine this specimen of a *Marsupite*, in which the bases of two of the arms are preserved (*Lign.* 154). A vertebral column attached to the central plate, at the base of this crinoidean, would convert it into an Encrinite; and in the large expanded plates of the receptacle, and the strong and simple ossicula of the arms, we have the elements of the more complicated and delicate fabric of the Lily Encrinite. In another specimen of Marsupite (now in the British Museum), the plates which covered the opening of the receptacle are preserved.* The Marsupite may therefore be considered as a free Crinoid, uniting the Comatulidæ with the Apiocrinidæ and their allies. The form of the perfect skeleton of the Marsupite was shown in a previous lecture, when treating of the Radiaria of the Chalk (p. 337).

42. PEAR-ENCRINITE (APIOCRINUS) OF BRADFORD.†—A smooth Crinoid, which, from the body having a pyriform shape, has received the name of Pear-Encrinite, occurs in considerable numbers in the Oolite near Bradford in Wiltshire, under the interesting circumstances already mentioned (p. 504).

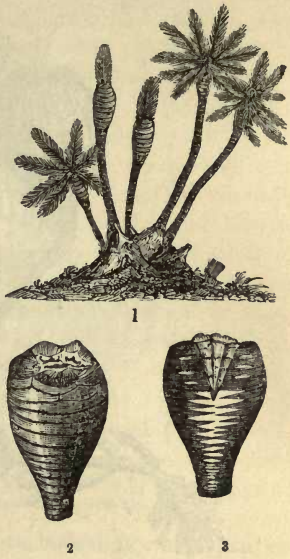
The receptacle or body-cup of this Encrinite is very smooth, and crossed transversely by fine lines where the plates of which it is composed unite. The stem is short, smooth, and strong; the arms are simple, and bear considerable resemblance to those of the Marsupite. In this drawing (*Lign.* 155, *fig.* 1), reduced from Mr. Miller's work on

* See Fossils of the South Downs, pl. XVI. fig. 6.

† Medals of Creation, p. 289; Pictor. Atlas, pl. L. figs. 1—8.

the Crinoidea, a group of these animals is represented as if alive in the water. A few perfect specimens have been obtained; but the body is usually found deprived of the arms, and broken off at the top of the column (*fig.* 2): the vertical polished section (*fig.* 3) shows the form and arrangement of the plates composing the receptacle or pelvis.

There is a crinoidal genus, termed *Bourgueticrinus* by D'Orbigny,* much resembling the *Apiocrinus* in miniature, and formerly confounded under the same name, that occurs plentifully in the Chalk of England and Europe, and has been found also in the London Clay. Parts of two species are figured in the *Medals*, vol. i. p. 291, *Lign.* 93.



LIGN. 155.—PEAR-ENCRINITE OF BRADFORD.

(*Apiocrinus Parkinsoni.*)

Fig 1. A group of Apiocrinites represented as alive in the water; some with the tentacula expanded, others closed.
2. Body of the Pear-Encrinite.
3. A vertical section of the same.

43. PENTACRINITES, ACTINOCRINITES, &c.† — In the Pentacrinus and closely allied Extracrinus,‡ the ossicula composing the columns are pentagonal, but in some species they have only four angles (*Lign.* 152, *fig.* 10); and in some the angles are acute, in others rounded. The stems are furnished with numerous side-arms (see the recent speci-

* Hist. Nat. Crinoides, 4to (unfinished).

† Medals, p. 294, *Lign.* 94: Buckland's Bridg. Treat. pl. 47—53.

‡ See the unfinished Monograph on Recent and Fossil Crinoidea, by Messrs. Austin, p. 95, &c.

men, *Lign.* 151), and the tentacula subdivide into innumerable branches, which terminate in delicate articulated rays.

LIGN. 156.—CRINOIDEA FROM THE MOUNTAIN-LIMESTONE AND SILURIAN FORMATIONS.

Fig 1. *Cyathocrinites pyriformis*, from the Wenlock limestone. (*Murchison's Silurian System*, Pl. 17, fig. 6.)

2. Restored figure of *Actinocrinus triacontidactylus* from the Mountain-limestone. (*Miller's Orinoidea*, p. 96.) *a*, the root-like processes of attachment; *b*, the side-arms; *c*, the pelvis; *d*, the arms or tentacula.

Allusion has already been made (p. 528) to the abundance and extreme beauty of the plumose Pentacrinites of the Lias-shale at Lyme Regis, and other localities in Yorkshire, Gloucestershire, and Somersetshire. See also *Lign.* 157.

Many other genera of this numerous family have been discovered, and are figured and described by palæontologists.* In some instances the receptacle appears to be

* For a more particular account of the natural history of this tribe of

closed, the tentacula being retracted or bent inwards, as if the animal had been in the act of conveying prey to its

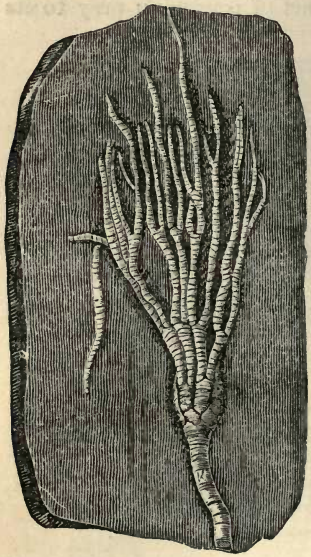
LIGN. 157.—PENTACRINITES SUBANGULARIS.*
In Lias Limestone, from Boll, Wirtemberg (one-sixth nat. size).

mouth, at the very moment of its becoming enveloped in its rocky sepulchre (*Lign.* 156, *fig.* 1). In other exam-

animals, besides the works by Parkinson, Miller, D'Orbigny, Austin, Phillips, and others, already referred to, see Forbes, Memoirs Geol. Survey, vol. ii., and Monog. Tert. Echin. (Pal. Soc.); Goldfuss, Petrif. Germaniæ, &c.; M'Coy, Palæoz. Foss. Cambridge Mus.; Hall, Palæont. New York; and especially the masterly history of the Crinoids of the Carboniferous System, by MM. L. de Koninck and H. le Hon (Mém. Acad. Roy. Belgique, 1854), which contains a remarkable register of nearly 350 books and memoirs, dating from 1558 to 1853, in which these interesting fossils have been described. Since 1853 Rœmer, Müller, Sandberger, Shumard, Wright, and others have added much to our knowledge of the Crinoids. Bronn's New Edition of his *Lethæa Geognostica*, and Pictet's *Paléontologie*, 2nd Edit. vol. iv., should be consulted for the latest résumés on the subject: these two works supply also beautiful series of illustrations of all the generic forms of this family.

* This is a portion of a beautiful specimen in the British Museum.

ples, the skeleton lies in relief, with the arms spread out, as if the creature, while floating at its ease in the water, had been suddenly surrounded and entombed in the mud (*Ligns.* 157, 158). The elegant plumose encrinite, termed *Actinocrinus*,* occurs in a beautiful state of preservation in the Mountain-limestone; the form of the original is well represented in the *Lign.* 156, *fig.* 2, p. 664. The receptacle of the Actinocrinite is constructed of numerous plates, which in many species are richly ornamented; and some have the surface granulated in a radiating manner, like those of certain varieties of the Marsupite. In another genus, the *Cyathocrinus* (*Lign.* 158), the receptacle is very simple, and composed of but few plates. The ossicula of the columns in the Actinocrinites and Cyathocrinites are round and smooth: a beautiful specimen of the cup-shaped Encrinite is represented, of half the natural size, in *Lign.* 158.



LIGN. 158.—CUP-LIKE ENCRINITE.
(Cyathocrinites planus.)
From the Mountain-limestone, Clevedon, Somersetshire.

44. PENTREMITES AND CYSTIDEA.—The species and even genera of the fossil Crinoidea† are so numerous, that their bare enumeration would require more space than we can allot to the subject, and I can only notice two other remarkable types.

* Signifying the Radiated, or Nave-and-spoke Lily-animal.

† M. Pictet enumerates upwards of a hundred genera.

Pentremites. These Lily-shaped animals seem to hold an intermediate space between the Echinites and the Encrinites. Their receptacle consists of five petaloid divisions united by corresponding series of plates, which meet in a point at the summit. Each petal is divided by a groove, and is perforated near the apex. They have a very short pedicle. These Crinoideans are so abundant in some of the cherty beds of the mountain-limestones of Kentucky,* that the rocks have acquired the name of Pentremital limestone. Six or seven species occur in the mountain-limestone of Yorkshire.

Cystidea. In the oldest of the fossiliferous strata there occur certain Crinoideans of a type which is supposed to be restricted to the older palæozoic periods. There are about fifteen species in Britain, chiefly of the genera *Echinosphærites* and *Pseudocrinites.* These fossils were distinguished by Von Buch † by the name of *Cystidea.* The receptacle is of an oval form, composed of numerous polygonal plates articulated together, and having the necessary apertures on the side of the cup required by the economy of the animal; it has a short pedicle. The Cystidea are supposed to be destitute of true arms. They comprise several genera, and are among the first forms in which the Crinoidea appear in the natural records of our planet.

I must here conclude this very general notice of the Crinoideans, a family which, though of excessive rarity in the present seas, swarmed in the oceans of the earlier epochs, in various modifications of form and structure, comprising numerous genera and species, all of which are now extinct.

45. CONCLUDING REMARKS. — From this review of the Polypifera and Crinoidea, we learn that an atom of living jelly floating in the ocean, and at length becoming affixed

* Say; Journal of the Acad. Nat. Sciences of Philadelphia, for 1820.

† Transact. Acad. Berlin; and Quart. Journ. Geol. Soc. vol. ii. part 2, Miscell. p. 20; and Austin, *ibid.* vol. iv. p. 291.

to a rock, may be the first link in a chain of events, which after the lapse of ages may produce important modifications in the physical geography of our globe. We have seen that the living polypes in their rocky habitations enjoy all the blessings of existence, and at the same time are the unconscious instruments of stupendous operations, which in after-ages may affect the destinies of mighty nations; and that the materials elaborated by their agency, and subsequently consolidated by chemical changes, may become the foundations of Islands and Continents, and constitute new and favourable sites for the abode of future generations of the human race.

And when we bring the knowledge thus acquired to bear on the natural records of our planet, and examine the rocks and mountains around us, we find that in periods so remote as to exceed our powers of calculation, similar effects were produced by beings of the same type of organization as those whose labours have been the subject of our contemplation. We are thus enabled to read the history of the past, and to trace the succession of events, each of such duration as to defy all attempts to determine with any approach to probability the period required for its development.

In fine, these investigations have shown us the marvellous structure of creatures invisible to the naked eye, their modes of life and action, and the important changes effected in the relative proportion of land and water, by such apparently inadequate agents. They have instructed us, that above, beneath, and around us there are beings so minute as to elude our unassisted vision, yet possessing sensation and voluntary motion, and each furnished with its systems of nerves, muscles, and vessels, and preying upon creatures still more minute, and of which millions might be contained in a drop of water; nay, even that these last are supported by living atoms still less, and so on—and on—until the mind is lost in astonishment, and can pursue the subject no further!

Thus are we taught,—

"That those living things
To whom the fragile blade of grass,
That springeth in the morn
And perisheth ere noon,
Is an unbounded world—
That those viewless beings,
Whose mansion is the smallest particle
Of the impassive atmosphere,
Enjoy and live like man!
And the minutest throb,
Which through their frame diffuses
The slightest, faintest motion,
Is fixed and indispensable
As the majestic laws
That rule yon rolling orbs!"

SHELLEY.

We have contemplated the results produced by these countless myriads of animated forms,—the excess of calcareous matter brought into the waters of the ocean consolidated by their influence, and giving birth to new regions; and we have obtained evidence that in the earlier ages of our globe, like effects were produced by similar living instruments. The beds of fossil coral are now the sites of towns and cities, whose inhabitants construct their abodes of the limestones, and ornament their temples and palaces with marbles formed of the petrified skeletons of the zoophytes which lived and died in oceans that have long since passed away!

Hence we perceive that He who formed the Universe creates nothing in vain; that His works all harmonize to blessings unbounded by the mightiest or the most minute of His creatures; and that the more our knowledge is increased, and our powers of observation are enlarged, the more exalted will be our conception of His wondrous works!

LECTURE VII.

THE CARBONIFEROUS SERIES.

1. Introductory. 2. The Carboniferous Series. 3. The Coal-measures. 4. Coal-field of Derbyshire. 5. Coalbrook Dale. 6. Nature of Coal-deposits. 7. Mode of Deposition of the Coal-measures. 8. The Great Dismal Swamp of Virginia. 9. Erect Trees in the Carboniferous Deposits. 10. Upright Trees at Wolverhampton and St. Etienne. 11. Upright Trees in the Coal-measures of Nova-Scotia and Cape Breton. 12. Coal-shales and Vegetable Remains. 13. Millstone Grit. 14. Carboniferous Limestone. 15. Derbyshire Lead-mines. 16. Carboniferous Rocks of Devonshire. 17. Trap-rocks and Trap-dikes of the Carboniferous Series. 18. Faults in the Coal-measures. 19. Geographical distribution of the Carboniferous Strata. 20. Carboniferous Rocks of North America. 21. Organic remains of the Carboniferous Series. 22. Organization of Vegetables. 23. Climate and Seasons indicated by Fossil Wood. 24. Microscopical examination of Fossil Trees. 25. Nature of Coal. 26. Liebig on the formation of Coal. 27. Bitumen, Petroleum, and Naphtha. 28. The Diamond. 29. Anthracite, Plumbago, &c. 30. Petrifaction of Vegetables. 31. Artificial Vegetable Petrifactions. 32. Silicification of Vegetables. 33. Fossil Plants of the Coal. 34. Equiscetaceous Plants. 35. Fossil Ferns. 36. Sigillaria. 37. Stigmaria. 38. Lepidodendron. 39. Coniferous Trees and Plants. 40. Flora of the Coal. 41. Atmospheric conditions during the Carboniferous period. 42. Formation of Coal-measures. 43. Coal-measures originating in submerged Lands. 44. Zoophytes and Echinoderms of the Carboniferous Series. 45. Shells of the Carboniferous Series. 46. Crustaceans and Insects. 47. Fishes of the Carboniferous Series. 48. Reptiles of the Carboniferous period. 49. Climate of the Palæozoic Ages. 50. Retrospect, and Botanical Epochs.

1. Introductory.—From the contemplation of the changes produced on the earth's surface by the agency of minute beings whose nature and economy are known only to the instructed observer, we resume the geological argument from which we have for a while digressed, and enter upon the examination of the series of strata deposited during the period immediately antecedent to the Permian formation described in the fifth Lecture.

The *Carboniferous series*, so named from its comprising the principal deposits of mineral fuel, consists, in England, of a great triple formation of, 1st (lowest), a group of calcareous

strata, locally interbedded with shales, sandstones, ironstone, and coaly beds (Mountain-limestone); 2nd, a group of gritty and sandy beds, also with some coal (Millstone-grit); 3rd, an argillaceous and sandy group, with little limestone, but much ironstone and bituminous shale, and with numerous intercalated seams and thick beds of the carbonized vegetable matter termed Coal.* Independently of the interest attached to these deposits from the immense accumulation of fossil plants of which many of them are wholly composed, this series involves the consideration of some very remarkable geological phenomena; for the manner in which such extensive layers of carbonized vegetable substances (like the intercalated masses of rock-salt in the red marls of the Trias, p. 541), unmixed with extraneous matter, were produced, is a problem difficult of solution, under certain conditions in which it is presented to our examination. The deposition of coal appears, as we shall presently show, to have taken place under various circumstances; the coal being in some cases associated with fresh-water, and in others with marine organic remains.

But, though from the vast importance of mineral fuel in an economical point of view to nations in an advanced state of civilization, and the botanical interest with which such extensive natural herbaria of the palæozoic ages are invested, the coal is generally regarded as constituting the essential feature of this epoch, yet it would be more philosophical to consider these intercalations of carbonized vegetables, like beds of shells, &c., as extraneous and accidental. We have already seen, that the formation of coal was not

* In the Crystal Palace Gardens has been constructed a section of the coal-measures, the natural rocks being used as the constituents. In Germany, Dr. Beinert has formed, in his beautiful gardens at Charlottenbrunn, a highly interesting artificial section of the coal-beds, with fine specimens of the fossil plants in place; and Prof. Goeppert has erected a still larger section in the Royal Botanic Gardens at Breslau. See H. R. Goeppert's Der Königl. Botan. Garten der Univ. Breslau, 8vo, 1857.

confined to the carboniferous system ;* but that beds of this substance (under the various forms of peat, brown-coal, lignite, jet, pitch-coal, cannel-coal, bituminous shale, slate-coal, anthracite, glance-coal, and common coal) have been and will be produced, wherever trees and plants are accumulated in sufficient quantity and under the requisite conditions.

The peculiar types of vegetable organization comprised in the flora of this period afford the only distinguishing characters of the beds of coal interpolated in the strata that were deposited during the ages intervening between the close of the Devonian epoch and the commencement of the Permian.†

The strata comprised in the Carboniferous series form two natural groups, as shown in the following table ; and I propose to consider, in the first place, the general features of the deposits, and their geographical distribution; secondly, the nature and formation of coal, and the characters of the fossil plants of which it is composed; and, lastly, to notice the animal remains, and take a retrospective view of the successive floras which have prevailed on the surface of the earth during the periods embraced by our geological investigations.

2. THE CARBONIFEROUS SERIES.—Though in England simply divisible into a threefold series of calcareous, aren-

* See Dr. F. Senft's "Classification and Beschreibung der Felsarten," 8vo, 1857 : also Dr. Geinitz's "Steinkohlen-Formation in Sachsen," fol. 1856. A resume of the latter of these valuable works is given by Col. Portlock in his Presidential Address to the Geological Society in 1857 (p. cxxv.). See also Sir R. Murchison's "Siluria."

† See remarks on the Coal of the Oolite, p. 513; of the Wealden, p. 405; of the Tertiary, p. 283 ; and in peat, p. 66. It should be remembered that coal occurs also in the Cretaceous Series (in Saxony and elsewhere), in the Oolitic and Liassic series (at Boll in Wirtemberg, at Seefeld in the Tyrol, and at Walgau in Bavaria, and in Banat, &c.), in the Triassic series of Germany, and in the Permian series of Saxony; also occasionally in the Devonian series: nor are the Silurian and Cambrian, and even the hypogene rocks, without their carbonaceous contents.

aceous, and argillaceous beds, the carboniferous system, even in the British Islands, becomes far more complicated in the details of its stratification. In Ireland it commences with an important division, comprising sandy and shaly beds "(Yellow Sandstone" * and "Carboniferous Slate," of Griffith), 2000 feet thick; and the limestone itself (5000 feet thick) is there separable into three great divisions. In the western counties of England, and in South Wales, these lowest sandstones, shales, and thin limestones are represented by from 100 to nearly 600 feet of laminated beds, with marine shells, fishes, and terrestrial plants; and in Fifeshire there is a thickness of 1500 feet of equivalent beds. In its extension northward of Derbyshire the Mountain- or Scar-limestone becomes more and more interstratified, in its higher portion, with shaly beds; and in the northern counties and in Scotland the great bulk of this characteristic limestone-formation is not only replaced by clays, sands, and calcareous shales, but these are intercalated with numerous coal-beds, often of considerable thickness; thus forming an important series of lower coal-measures, the representatives of which exist also in Europe and in Nova Scotia. The following tabular arrangement exhibits the lithological characters and relations of the carboniferous deposits.

* Brit. Assoc. Report, 1852, Sect. p. 43. The "Yellow Sandstone" is correlated by Godwin-Austen (Geol. Quart. Journ. vol. ix. p. 244) with the Pilton and Petherwin beds of North Devon, and referred by him, with the Yellow Sandstones of the Boulonnais and the Cypridina-schists of Germany, to the Upper Devonian. To this member of the Palæozoic series Sedgwick has also provisionally referred it (Phil. Mag. 1854, vol. viii. p. 364, and Geol. Journ. vol. viii. p. 8). Dr. Sharpe, however, inclined to the collocation of the Petherwin group with the Carboniferous system (Geol. Quart. Journ. vol. ix. p. 247). It may therefore be said of these beds of passage from the Devonian to the Carboniferous system, as of the transitional beds between the Silurian and Devonian, the Carboniferous and Permian, the Trias and Lias, the Lias and Oolite, &c., that much exact observation has still to be made in these and other closely related instances.

CARBONIFEROUS SYSTEM.

UPPER. (Upper coal-measures.)

1. COAL-MEASURES;—divisible * into Upper, Middle, and Lower (or "Ganister") series. Grit, sandstone, and shale or clay, with numerous beds of coal; ironstone, in nodules and irregularly stratified; and occasional intercalations of limestone-bands. Fossil reptiles and fishes; molluscs (chiefly freshwater), annelids, insects, and crustaceans are not uncommon in some parts. Thickness upwards of 4000 feet in some districts of England.
2. MILLSTONE-GRIT.—Coarse quartzose sandstone, passing into grit and conglomerate, used for millstones (hence the geological term), with shales and sandstones; containing the trails of molluscs and annelids, rare traces of reptiles, and interspersions of fossil plants and vegetable matter, and sometimes layers of coal. Thickness about 800 feet.

LOWER. (Lower coal-measures, or the mountain-limestone group.)

3. UPPER LIMESTONE-SHALES or YOREDALE ROCKS.—Alternations of limestones, shales, and sandstones; with some chert, rottenstone, ironstone, bitumen, and coal; marine shells (*Goniatites*, *Orthoceras*, *Productus*, and *Posidonomya*; *Encrinites*, &c.): thickness about 500 feet.
4. MOUNTAIN-LIMESTONE or SCAR-LIMESTONE.—A series, upwards of 1000 feet in thickness, of massive limestones, shales, and flagstones, with dolomite, bitumen, rotten-stone, chert, galena, and iron-ore; corals, crinoids, and marine shells in profusion, and some trilobites. Beds of marble wholly made up of petrified zoophytes or of crinoids. This group is devoid of coal in South-western and Central England; but the mountain-limestone of Westmoreland, Northumberland, Fifeshire, and some parts of Europe and North America, contains extensive coal-beds, with occasional tracks of reptiles.

* In the southern coal-fields two divisions only are apparent: Murchison's "Silurian System," chap. 6.

5. Lower Limestone-shale. — Alternating shales, sandstones, and limestones; with posidonomya, orthis, and spirifer; abundance of fish-remains, coprolites, and cypridæ; and some remains of plants. About 400 feet thick.

3. The Coal-measures. — The bituminous substance termed coal is simply vegetable matter altered by chemical changes, which will hereafter be considered. It occurs in beds that vary from a few inches to a fathom or more in thickness, and are interposed between strata of shale, clay, micaceous sandstone, limestone, and ironstone; alternations of this kind, occupying circumscribed areas, are termed *coal-basins*. Mr. Bakewell observes that the strata thus disposed may be imitated by a series of mussel-shells or saucers placed one within the other, and having layers of clay interposed. If one side of the series be raised to indicate the general rise of the strata in that direction, and the whole be dislocated by cracks, the general arrangement of the beds and the displacements which they have undergone will be represented; each shell representing a bed of coal, and the partitions of clay imitating the earthy strata which separate the carbonaceous layers.

It is the association of iron-ore with the limestone that serves as a flux, and with the mineral fuel required for the reduction of the ore into a metallic state, that has given rise to the numerous iron-foundries established over the sites of our principal coal-fields. The usual characters of a *Coal-field*, as a series of strata of this kind is termed, are shown in the section of that of South Gloucestershire (*Lign.* 124, p. 522). Here we perceive that the Devonian or Old Red Sandstone has been elevated into a position almost vertical, and that the *Mountain-limestone*, which lies immediately upon it, partakes of the same inclination. This is succeeded by conformable beds of *Millstone-grit*, which are followed by alternations of Coal and shales; the *Permian* and *Triassic*

beds, the *Lias*, and *Inferior Oolite* (3, 4, and 5) are seen above in an unconformable position. The *Mountain-limestone* and *Millstone-grit* (1, 2) also appear on the opposite flank of the elevated ridge of the Mendips. The chronological order of the deposits exhibited in this section, that is, the succession according to their original position before they had suffered displacement, is as follows: immediately overlying the lowermost or most ancient, the Devonian strata of the Mendip Hills, we have — 1. Mountain-limestone.—2. Millstone-grit; upon this are alternations of Coal, shale, and grit.—3. Permian and New Red Sandstones. —4. Lias.—5. Inferior Oolite.—6. Great Oolite.—7. Oxford Clay, south of Malmesbury.

The term *basin*, applied to these accumulations of carboniferous strata, must be taken in a general sense; for, though some of these groups of deposits may have been formed in circumscribed depressions, it is evident that, in general, the beds have originally extended over large areas, and that their present isolated position and confined limits are attributable to subsequent elevations and depressions by which the "faults" or dislocations of the coal and associated strata of the rocks on which they repose have been produced. Extensive denudations have completed the separation of the coal-basins.

Of the English coal-fields, those of Newcastle, Durham, Yorkshire, Lancashire, Flintshire, Cheshire, Derby, Nottinghamshire, Leicestershire, and Warwickshire have many features in common; those of South Staffordshire and Worcestershire are related more nearly to each other than to the other coal-fields; and those of Glamorganshire, Monmouthshire, Gloucestershire, and Somerset form another allied group.* The coal-measures of the northern counties are divisible into a triple series—upper, middle, and lower; the last, also known as the "Ganister series," contains in Yorkshire a single shale-bed of marine origin, with *Goniatites*, *Posidonomyæ*, and fishes. Other instances of the irruption of sea-waters into the generally fresh-water area of the coal-measures,—the last efforts, as it were, of the old carboniferous ocean to regain possession of the

* Phillips' "Manual of Geology," 1855. Both this valuable elementary work and Prof. Ansted's "Elementary Course of Geology," 1856, contain particulars of the relative extent of the English coal-fields, and of the thickness and character of their respective coal-beds.

rapidly shallowing region,—are evidenced by occasional marine deposits in the coal-fields of Lancashire, Dudley, and Coalbrook-dale.

4. Coal-field of Derbyshire.—The Derbyshire Coal-field will serve as a type of the English series.

The strata of Carboniferous Limestone which form the grand mountain-chains of Derbyshire decline towards the eastern side of the county, and sink beneath the Coal-measures. Immediately upon the limestone are beds of calcareous slate or shale, about four or five feet in thickness (known as the "Limestone-shale," and equivalent to the Yoredale rocks of Yorkshire), intercalated with grit-stones, and about four or five hundred feet in thickness. This series of alternating beds, compact and soft, coarse and fine, many of which readily disintegrate from weather-action, forms the exposed face of Mam Tor, or the "*shivering mountain*," near Castleton. They are succeeded by a mass of grit, or conglomerate, with vegetable remains, which is worked for mill-stones. Above the Millstone-grit are the regular Coal-strata, comprising sandstones of various qualities, and often in exceedingly thin laminæ,—indurated clay-beds,—iron-stones, the nodules of which contain organic remains,—and softer argillaceous beds, which, being of a slaty structure, are called *shales*. Two of the layers of clay, termed *mussel-bind*, abound in bivalve shells, somewhat resembling fresh-water mussel-shells, but of extinct types of forms. The total thickness is 1310 yards, which includes thirty different beds of coal, varying from six inches to eleven feet, and making the amount of coal about twenty-six yards. In the shales below the coal there is a transition from calcareous strata, with marine animal remains, to fresh-water mud-deposits, with terrestrial vegetables: this may have originated from occasional intrusions of freshets from a river.

The series above enumerated is often repeated; shales, clays, and sandstones occurring under different beds of coal, with a great similarity in the succession and thickness of each. Interruptions to the continuity of the beds, from cracks and fissures which have taken place since the original deposition of the strata, are everywhere apparent. Dikes or intrusions of extraneous mineral matter are of frequent occurrence, separating the strata by vertical walls, which are from a few inches to many yards in thickness. These extraneous masses sometimes consist of indurated clay, but more commonly of the ancient volcanic rock termed *basalt* or *trap*.

5. Coalbrook Dale.—In Shropshire the carboniferous strata are exposed over several detached areas.*

* Consult Sir R. I. Murchison's admirable description of the Carboniferous System; "Silurian System," chap. vi.

Near Shrewsbury the coal-beds are associated with limestone, of fresh-water or estuary origin, and containing minute entomostraca (*Cypridæ*), annelids (*Serpulæ*),* shells (related apparently to *Modiola* and *Unio*),† and fishes. But the most important and productive carboniferous tract in Shropshire is *Coalbrook Dale*, which is situated on the east side of the range of rocks forming the Wrekin and Wenlock Edge, the coal-strata being superposed on mountain-limestone; it contains beds and nodules of iron-stone, enclosing organic remains. This coal-field ‡ is remarkable for the dislocated and shattered condition of the strata, and the intrusion of volcanic rocks; the latter do not appear as dikes or veins, in the fissures of the beds, but rise up in mounds or protuberances. The walls of the fissures are in some instances several yards apart, the intervals being filled with debris. Strata containing marine shells alternate with others abounding in fresh-water shells and land-plants, as in Derbyshire. These alternations prove that these coal-measures were deposited in an estuary, subject to occasional freshets from a considerable river; the frequent alternations of coarse sandstones and conglomerates with beds of clay and shale, containing the remains of the plants brought down by the river, support this opinion. The strata forming this carboniferous series consist of quartzose sandstone, indurated clay, slate-clay, and coal. A pit sunk in Madely colliery, to a depth of 730 feet, passed through eighty-six beds of alternating quartzose sandstone, claystone porphyry, coal, and indurated clay containing nodules of argillaceous ironstone. The sand-

* These little *Serpulæ* have been described as planorboid molluscs, under the name of *Microconchus;* but there is no doubt of their being true Serpulæ, as pointed out by Mr. E. W. Binney (Memoirs Phil. Soc. Manchester, vol. x. p. 196). They are frequently attached to vegetable fragments. In Nova Scotia these little annelids occur plentifully under the same conditions; indicating in some instances the drifting of plants in sea-water, and in others the advance of estuarine waters over submerged jungles. A similar form is found on the fossil plants of the Mountain-limestone of Northumberland (G. Tate, Flora M. L. pl. xiii. fig. 6), and on the marine shells in the coal-measures of Coalbrook Dale (Geol. Trans. 2nd ser. vol. v. pl. 40, figs. 1, 3, 5), and also attached to the fossil shells and corals in the Devonian rocks of Russia and the Eifel (*Spirorbis omphalodes*, Goldfuss).

† Probably *Myalina* and *Anthracosia*, of King. Such as these occur also in the coal-measures at the Joggins in Nova Scotia, Quart. Journ. Geol. Soc. vol. x. p. 12 and p. 39, figs. 22—25.

‡ See a highly interesting memoir on this coal-field, by Mr. Prestwich, Geol. Transact. 2nd ser. vol. v. p. 413; also Murchison's "Silurian System," chap. vii.

stones of Coalbrook Dale are fine-grained and micaceous; and some beds are penetrated by *petroleum*, which at Coalport escapes from the surface in a tar-spring; bitumen also occurs in some of the shales. Plants, shells, and crustaceans * are abundant in the shale and iron-stone nodules; and the remains of insects are sometimes met with.†

6. NATURE OF COAL-DEPOSITS.—This brief notice of two of the British coal-fields will serve to convey a general idea of the strata of which a coal-basin consists.‡ But it is necessary to enter more particularly on the nature and arrangement of the beds of coal, and their associated deposits; for, though many accumulations of carboniferous rocks have manifestly been formed by different and local agencies, the grand series of ancient coal-measures, setting aside unimportant discrepancies, present a remarkable uniformity of character, not only throughout Great Britain and Europe, but also in most other parts of the world.§

* Both Cypridiform and Limulus-like Entomostracans. Prestwich, *loc. cit.* pl. 41.

† Medals of Creation, vol. ii. p. 554.

‡ In a little anonymous work, entitled "Our Coal and Our Coal-pits," published in 1853 (Longman), the reader will find a vast deal of good information about coal-seams and coal-pits, such as certainly has not been brought together in any other work, but which is of interest and value both to the geological and the general student.

§ The various Memoirs on the British Coal-fields in the Geological Society's Transactions and Journal, in the Reports of the British Association, and in the Transactions of the Northumberland, Manchester, and other Societies, by some of our most eminent observers; and in the works of Lindley and Hutton, Holmes, Mammatt, Mushet, D. Milne, Hibbert, Bakewell, Conybeare, Ansted, Phillips, Lyell, De la Beche, Buckland, Murchison, and others, will afford those who wish to pursue the inquiry, information of the most important and interesting nature. The Coal-fields of Ireland have been described by Weaver, Griffith, and Portlock. "The Annales des Mines" and "Bulletin Soc. Géol. France" are rich with notices of the Belgian and French coals; and Godwin-Austen and Sharpe have also treated of the Boulonnais and Belgian Coal-fields in the Geol. Soc. Journal, to the 12th vol. of which MM. Degousée and Laurent have contributed a valuable notice of the Valenciennes

We have seen that the strata constituting a coal-field are alternating layers of coal, clay, shale, and sand, of variable thickness, usually based either on grit, or on limestone abounding in marine shells and corals. Now, a very remarkable fact is the nearly uniform presence of an often thick bed of earthy clay beneath every layer of coal, and a stratum of slaty clay or shale above it; together forming a triple series, presenting the following characters:—

(1.) Lowermost;—a stratum of clay, called, from its position, the *Under-clay;* a tough argillaceous substance, which upon drying becomes a grey friable earth. Occasionally this clay is of a black colour from the presence of carbonaceous matter. This bed almost invariably contains an abundance of the fossil vegetables termed *Stigmariæ*,* which are root-like bodies, generally of considerable length, and have rootlets or fibres attached, which extend in every direction through the clay. These great roots commonly lie parallel with the planes of the stratum, and nearer to the top than to the bottom.

(2.) *Coal.* A carbonized mass, in which both the external forms and internal structure of the plants and trees composing it are almost entirely

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Coal-basin. Naumann, Hoffmann, Sternberg, Villefosse, Rœmer, Dechen, Herzog, Gutbier, Freiesleben, Leonhard, Cotta, Geinitz, Gœppert, and Beinert are chief among those who have treated of the Coal-fields of Germany. The coal of Russia is described in full by De Verneuil, Keyserling, and Murchison.

A long series of papers having reference to the Coal-fields of New Brunswick and Nova Scotia, published in the Proceedings and Quarterly Journal of the Geological Society, are enumerated in an appendix to Mr. Dawson's very instructive account of the Joggins Coal-measures in the 10th vol. of the Geol. Society's Journal (p. 41). The "Acadian Geology," by the same author, is also an important work in the literature of the coal. Mr. W. R. Johnson's "Report on American Coals," 1844, and especially the late R. C. Taylor's valuable "Statistics of Coal," should be consulted by the student, where abundant references to books and papers treating of British, European, American, African, Asiatic, and Australian coals will be found.

* See the description of coal-plants further on; also Medals of Creation, p. 133; Pict. Atlas, Org. Rem. pl. 3, *fig.* 1, and plates 21—23; and the Supplementary Notes, Pict. Atlas, p. 198.

obliterated, though traces of woody tissue are observable. Large trunks, stems, and leaves are rarely distinguishable in it.

(3.) *The Roof*, or upper bed. This generally consists of slaty clay, abounding in trunks, branches, leaves, and fruits; it also includes layers and nodules of iron-stone, enclosing leaves, insects, crustaceans, &c. In some localities argillaceous or calcareous beds of fresh-water shells, and in others of marine shells, are intercalated; and layers of shale, finely laminated clay, micaceous sand and grit, and pebbles of limestone, granite, sand-stone, and other rocks often occur. Pebbles of iron-stone, and even of coal, derived from the destruction of older iron-stones and coal-beds, have been found in coal-seams. Some of the most illustrative specimens of the leaves, fruits, &c. of the carboniferous flora are found in these shales and sandy beds, which appear to have been the accumulations of water-worn detritus of other rocks, promiscuously intermingled with the dense foliage and stems of prostrate forests; the whole having been drifted from a distance by strong currents or floods, proving that considerable time elapsed during the formation of these coal-measures,—sufficient indeed for the consolidation and denudation (and possibly upheaval also) of one set of deposits before the later beds were formed.* The evidences of the partial removal of coal-seams, shales, and sand-beds, in the coal-measures, point also to the length and many changes in the coal-era.†

7. MODE OF DEPOSITION OF THE COAL.—Thus we find, in the first place, spread uniformly over the bottom, and constituting the foundation on which the coal reposes, a stratum of fine clay (under-clay), sometimes several feet thick, which possibly may have once constituted the soil of vast plains or savannahs. Almost the only fossil remains found in it, except in a few localities, are the roots of the large trees of which the coal is in a great measure composed; for such the common *Stigmariæ* now prove to be, and not floating aquatic plants, as was formerly supposed. The invariable occurrence of the fossil roots, termed *Stigmariæ*, in the under-clay, and their rarity in the coal and shale, was noticed by Martin (*Petrif. Derbiensia*), Steinhauer, Maccul-

* See De la Beche's Geol. Observ. 2nd edit. p. 511.

† *Ibid.* p. 514; and Quart. Journ. Geol. Soc. vol. vi. p. 124; vol. vii. p. 246; and vol. x. p. 12. Rep. Brit. Assoc. 1838, Sect. p. 79.

loch, and other observers: but the importance of this fact was not duly appreciated until Logan drew attention to it. In the Welsh coal-field, in a depth of twelve thousand feet, there are sixty beds of coal, each lying on a stratum of clay abounding in Stigmariæ. In the Appalachian coal-field of the United States, and in the well-exposed coast-sections of the Coal-formation in Nova-Scotia, the same phenomenon appears.

Upon this under-clay is a bituminous mass of indistinguishable plant-remains (*Coal*). Occasionally stems of trees are found passing vertically through or lying in the coal-bed.

In the third place, we have a deposit of drifted materials promiscuously intermingled with the foliage and stems of numerous kinds of terrestrial plants (*Roof*); the whole often appearing to have been subjected to the mechanical action of water, both in its origin, and sometimes after its first deposition as a sand or mud-bed.

These facts seem to indicate that a bed of coal of this kind may have been either a submerged forest or a swampy jungle. The *under-clay* was the natural soil in which the Stigmariæ, the roots of the trees (Sigillariæ) forming the coal above, originally grew; the *coal*, the carbonized stems and foliage of the trees to which the roots belonged; and the upper stratum, or *roof*, may have either resulted from detritus transported from a distance by a debacle or flood, which overwhelmed and buried the foliage and stems of the prostrate forest, or may have been swept over it more or less rapidly by the encroaching tides on a low and sinking well-forested coast-line.

These phenomena may thus be explained by supposing that a plain, densely clothed with vegetation, was inundated by an irruption of the sea; or overwhelmed by a flood of water from an inland lake, occasioned by the sudden removal of some barrier; or by the slow subsidence of the tract of country on which the forest or jungle grew. But when we find an uninterrupted series, in which triple deposits of this kind are repeated

thirty or forty times, and through a thickness of several thousand feet, this solution of the problem, though very plausible, is not without its difficulties. Not only subsidence after subsidence must have taken place, but the first submergence have been followed either by an elevation of the land, or a very gradual reconstitution of a sub-aërial surface; and then another soil capable of affording support to a second forest must have been produced, and another generation of vegetables, of the same species as the former, have sprung up, and arrived at maturity: and again another subsidence, followed by an accumulation of drift. And these periodical oscillations in the relative level of the land and water, and successive reproductions of vegetable soil and of forests, must have gone on uninterruptedly through an incalculably long period of time; not in one district or country only, but in various parts of the world, during the same geological epoch.

Some seams of coal attain an enormous thickness. In England, the thickest bed of coal, amounting to thirty feet, is in the Dudley basin. In the Great Exhibition of 1851, there was exhibited a fine section of the lowermost bed of coal (known as the "Thick Coal"*), from Tividale colliery in South Staffordshire, the total thickness of which was 29 feet; with no intermixture of sediment except some shaly partings, a few inches thick. A shed was erected for its exhibition on the outside of the west-end of the Crystal Palace; beside it were placed some large stems of Sigillariæ.

"It is not, however, to be supposed," says Prof. Phillips,† "that this enormously thick seam is a single bed of coal; it is, in fact, composed of thirteen different beds locally accumulated together, with certain partings, which in other places swell out into considerable thicknesses of shale. Thus the upper part of the 'ten-yard coal' separates from the rest of the beds, and under the title of the 'flying reed,' becomes a totally distinct bed in the northern part of the coal-tract." ‡

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* See Jukes's Memoir on the South Staffordshire Coal-field (Geol. Surv. Records), 1853, p. 173, 184, &c. This careful and well-illustrated description of a typical coal-field contains not only the good practical information to be expected from the labours of so sound a geologist as Mr. Jukes, but also many valuable theoretical suggestions on the origin of coal and the physical characters of the old carboniferous area.

† Manual Geol. p. 192.

‡ Humboldt refers also to some very thick coal-seams in Scotland and Burgundy, *Cosmos*, vol. i. p. 284. For Mr. Bowman's views of the probable circumstances under which separate coal-seams run into each other, see Lyell's "Manual," p. 330.

Mr. Dawson describes the "Main-coal Seam" of the Albion Mines (New Brunswick), a specimen of which was extracted by Mr. H. Poole for the New York Exhibition, 1853, as being 38 feet 6 inches thick, of which only 2 ft. 4½ in. consisted of the "roof-shale," intercalated carbonaceous shale and ironstone, and "under-clay." *

In some districts (as in the coal-beds of the Mountain-limestone of Southern Russia and of the North of England) the vegetables of which the coal is formed apparently consist of broken and drifted plants, carried into the sea by inundations and freshets of rivers; in this case, the layers of clunch or finely levigated shale which support the coal-seams may have originated from the earthy debris brought down by the floating masses of terrestrial plants.†

8. THE GREAT DISMAL SWAMP OF VIRGINIA. — The formation of the coal-measures from terrestrial trees and plants, not drifted, but growing on the areas now occupied by the coal, is strongly advocated by Sir C. Lyell: and the following notes from the observations of this profound geologist, on the "*Great Dismal Swamp*" of Virginia, in North Carolina, afford an interesting illustration of this hypothesis.

The "Great Dismal," is a morass forty miles long, and twenty-five miles in its greatest width, and has the appearance of a broad inundated river-plain, covered with all kinds of aquatic trees and shrubs, the soil being as black as in a peat-bog. It is one enormous quagmire, soft and muddy, except where the surface is rendered partially firm by a

* Quart. Journ. Geol. Soc. vol. x. p. 47.

† Sir R. I. Murchison.—The following remarks of an eminent French geologist, Constant Prévost, are especially worthy of attention in relation to this subject:—"On n'a pas assez réfléchi lorsque l'on a dit que les formations fluvio-marines n'étaient que des accidents locaux d'embouchure et de golfe; on pourrait presque avancer, sans paradoxe, que dans certaines mers bordées de vastes continents, les eaux douces affluentes produisent plus dans la mer, que les eaux marines elles-mêmes. Le Mississipi et ses tributaires enlèvent au continent qu'ils traversent plus de matieres sédimentaires et de corps organisés, pour les porter dans la mer, que les vagues de celles-ci n'en prennent sur tout le pourtour des deux Amériques; et l'on sait, par de journaliers exemples, que des végétaux apportés par ce fleuve, des rives du Missouri dans le golfe du Mexique, vont atterrir sur les côtés d'Islande, et même du Spitzberg."—*De la Chronologie des Terrains et du Synchronisme des Formations.* 1845.

covering of vegetables and their matted roots; and is actually higher than nearly all the firm and dry land which encompasses it; and, to make the anomaly complete, in spite of its semi-fluid character, it is higher in the interior than towards the margin. The soil of the swamp is formed of vegetable matter, usually without any admixture of earthy particles. We have here, in fact, a deposit of peat from ten to fifteen feet in thickness, in a latitude where, owing to the heat of the sun and length of the summer, no peat-mosses like those of Europe would be looked for under ordinary circumstances. The juniper trees, or white cedars (*Cupressus thuyoides*), stand firmly in the softest part of the quag-mire, supported by their long tap-roots, and afford, with many other evergreens, a dark shade, under which a multitude of ferns, reeds, and shrubs, from nine to eighteen feet high, and a thick carpet of mosses, spring up, and are protected from the rays of the sun. Where these are most powerful, the large cedar (*Cupressus disticha* or *Taxodium distichum*) and many other deciduous trees are in full leaf. The black soil formed beneath this shade, to which the mosses and leaves make annual additions, is a soft black mud, without any traces of organization. Numerous trunks of large and tall trees lie buried in the black mire of the morass. In the midst of the swamp there is a lake of an oval form, seven miles long, five wide, and the depth, where greatest, fifteen feet; its bottom consists of mud like the swamp, but which in some places is covered by a pure white sand, a foot deep. This sheet of water is usually even with the banks, on which a tall and thick forest grows.

The phenomena above described help us greatly to conceive the manner in which the coal of the ancient carboniferous rocks may have been formed. The heat, perhaps, may not have been excessive when the coal-measure originated, but the entire absence of frost, with a warm and damp atmosphere, may have enabled tropical forms to flourish in latitudes far distant from the line. The frequent submergence of masses of vegetable matter like the morass, beneath seas or estuaries, as often as the land sank down during subterranean movements, may have given rise to depositions of strata of mud, sand, or limestone, immediately upon the vegetable matter. The conversion of successive surfaces into dry land, on which other swamps supporting trees were formed, might give origin to a continued series of coal-measures, of great thickness.*

The above is a concise exposition of this theory by one of its ablest advocates, and is therefore deserving every consideration; and the more so, since the same philosophical

* Travels in North America, vol. i. chap. vii.

observer has brought forward a plausible explanation of the perplexing enigma presented by the purity of the coal itself from sandy and earthy particles, and by the comparatively great thickness of many coal-seams. He adduces as illustrative of the probable origin of such coal-beds, the existing conditions of the "Sunk Country," in the valley of the Mississippi, and other of the great "cypress-swamps" of that region, where great areas of rapidly accumulating vegetable matter are protected by thick marginal belts of reeds and brushwood, which effectually resist the introduction of any of the detrital matter suspended in the waters of the annual inundations.*

9. UPRIGHT TREES IN THE COAL-MEASURES.—The occurrence of trees in an upright position, in some instances with their roots attached, and extending into the under-clay, is regarded as another unequivocal proof of the formation of coal from vegetables growing on the spot.

Several instances of this kind have been observed in England. One of the most remarkable was brought to light (from 1837 to 1846), in the excavations for the Bolton and Manchester Railway, near Dixonfold, where five large stems (*Sigillariæ*) were found erect, with their roots extending into a layer of impure clay below, in which were found many specimens of the fossil cones known as *Lepidostrobi*.† They stood on the same plane, and near to each other. The trunks were surrounded and filled by a soft blue shale, the carbonized bark (or, rather, the thin outer cylinder of woody tissue) being all that remained of the original structure. The stems are gnarled and knotted, and have decorticated prominences, like those in barked trunks of our old dicotyledonous trees. All these trunks appear to have been broken off by violence at a height of four or

* Manual of Geology, 5th edit. p. 385. The subject of the origin of coal-beds, both on the hypothesis of the accumulation of plants growing in place, and on that of the drifting of masses of plants, is ably treated in De la Beche's "Geological Observer," and in Phillips' "Manual of Geology." See also Williamson's Remarks, Rep. Brit. Assoc. 1842, Sect. p. 48.

† Medals, p. 141.

five feet above the roots, and no traces of the upper part of the stems or branches were detected.*

Mr. Binney has described a very interesting specimen of a rooted stump of a Sigillaria met with in a colliery at Dunkinfield, about seven miles east of Manchester.†

In constructing the railway-tunnel at Clay-cross, a few miles south of Chesterfield, through the middle portion of the Derbyshire coal-measures, in 1838, a group of nearly forty trees (*Sigillariæ*) was discovered. These stood at right angles to the planes of stratification, and not more than three or four feet apart.‡

In the Derwent Mines, Durham, at the depth of fifty-five fathoms, among numerous examples which were lying in horizontal layers, were several in an erect position. Two stems of Sigillariæ, situated in the space cleared out to get at the lead-ore, stood upright, having their roots firmly impacted in a bed of bituminous shale; they were five feet high, and two in diameter.‖

In the Newcastle coal-field, a stratum of sandstone occurs 150 yards below the surface, in which were observed many erect stems of trees, from two to eight feet in circumference, having their roots in a thin layer of coal.§

On the coast of Northumberland, within the length of half a mile, twenty upright trees were observed in 1816, by Mr. Trevelyan;¶ and similar fossils were noticed many miles distant from this spot, in the same coal-field, as if they were a continuation of a submerged forest, the trees of which had maintained their erect position, like those of the Isle of Portland (p. 399). Examples of isolated upright trunks, with more or less of the roots attached, are not uncommon.

In Glamorganshire De la Beche and Logan observed a fine group of upright Sigillariæ.**

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* Medals, p. 125; Geol. Transact. 2 ser. vol. vi. p. 173, pl. 17; and Geol. Proceed. vol. iii. p. 139 and 269. Owing to the scientific zeal of Mr. Hawkshaw, F.G.S., who originally described these interesting relics, of a palæozoic forest, they have been carefully preserved in their natural position. See also Trans. Manchester Geol. Soc. vol. i. p. 112.

† Geol. Journ. vol. ii. p. 390.

‡ Geol. Proc. vol. iii. p. 272.

‖ Observations on Fossil Vegetables, by Henry Witham, 4to; Edinburgh, 1831, p. 5.

§ *Ibid.* p. 7.

¶ Buckland Bridg. Treat. p. 470.

** Mem. Geol. Survey, vol. i. p. 183.

10. UPRIGHT TREES AT WOLVERHAMPTON AND ST. ETIENNE.—The following examples may also be adduced.

In a colliery near Wolverhampton the bottom coal rises to view, and where the surface has been cleared of the alluvial covering, it presents "the appearance of a moor on which a full-grown fir-wood had been cut down a few months before, and only the stumps left behind. Stump rises beside stump, to the number of seventy-three in all: the thickly diverging roots strike out on every side into what had been once vegetable mould, but which now exists as an indurated brownish-coloured shale. Many trunks, sorely flattened, lie recumbent on the coal, some of them full thirty feet in length, while some of the larger stumps measure rather more than two feet in diameter. There lie thick around Stigmariæ, Lepidodendra, Calamites, and fragments of Ulodendra; and yet, with all the assistance which these lent, the seam of coal formed by this ancient forest does not exceed five inches in thickness. . . . . Not a few of the stumps in this area are evidently water-worn. . . . . The prostrate forest had been submerged, and mollusks lived and fishes swam over it." This upper forest is underlaid by a second, and even a third; we find three full-grown forests closely packed up in a depth of not more than twelve feet.*

A coal-pit at Treuille, near St. Etienne, Department of the Loire, in France, described by M. Alexandre Brongniart, contains many stems of Calamites and other trees in an erect position; and this fact is generally considered as an indisputable proof that the coal was produced by the submergence of a forest that once grew on the spot: but as many of these stems are inclined at various angles, and their roots implanted in different beds, the perpendicularity of the upright trees is possibly accidental. This mine is most favourable for observation, for it is in the open air, and exposes to view a natural section of the strata of clay, shale, and coal, with four layers of compact iron-ore, in flattened nodules, which are accompanied, and even penetrated, by vegetable remains. The upper ten feet of the quarry consist of micaceous sandstone, which is in some instances stratified, and in others possesses a slaty structure. In this bed are numerous vertical stems traversing all the strata, and appearing like a forest of plants resembling the Bamboo or large *Equiseta*, turned into stone, in the place on which it grew. The stems are of two kinds:

* First Impressions of England and its People, by Hugh Miller, p. 223 (Edit. 1857, p. 202). This fossil forest is described and illustrated by Messrs. H. Beckett and W. Ick, in the Geol. Soc. Journ. vol. i. p. 41.

the one long and slender, from one to four inches in diameter, and nine or ten feet high, being simply jointed and striated solid cylinders of sandstone, with a thin coaly bark; the other and less common species are hollow cylindrical stems, spreading out from the base like a root, but without ramifications.*

11. Upright Trees in the Coal-Measures of Nova Scotia and Cape Breton.—Numerous erect trees in the Cape Breton coal-measures have been observed and described by Mr. R. Brown,† many them having their roots and rootlets still attached. And, though it is unnecessary to multiply examples of the occurrence of trees in an upright position in the carboniferous deposits, this phenomenon is so strikingly displayed in the coal-measures of Nova Scotia, and has been so well described by Logan, Dawson, and Lyell, that I cannot omit a short account of the erect stems in the cliffs of the Bay of Fundy:—

In the coal-measures on the southern shores of a branch of the Bay, there are ten successive stages of erect trunks of trees, placed at right angles to the planes of stratification, through a thickness of strata of 2500 feet; the entire series of deposits is estimated to be five miles in thickness. The strata are inclined at an angle of between 25° and 30°. The trunks of the trees are often mere hollow cylinders, consisting of the bark in the state of pure coal, and filled with sand and clay, containing leaves of ferns and other plants, and in one instance the bones of a small reptile and the shell of a land-snail.‡ A trunk, fourteen inches in diameter, had a coating of bark a quarter of an inch thick. Beds of bituminous shale and clay with Stigmariæ, ten feet thick, are described as overlying one series of upright trees, and upon these was another bed of coal, one foot thick, that supported two trees, each eleven feet high, and sixty yards apart.§

* Notice sur des Végétaux Fossils traversant les couches du Terrain Houiller, par M. Alex. Brongniart, Paris, 1821. See also De la Beche's "Geological Memoirs," 1824, for a translation of M. Beaunier's description of the coal-district of St. Etienne, with a drawing of the quarry and upright stems.

† Geol. Soc. Proceed. vol. iv. p. 176; Journ. vol. ii. p. 393; vol. iv. p. 46; and vol. v. p. 354. ‡ Journ. Geol. Soc. vol. ix. p. 58.

§ See the Section of the Cliffs of the South Joggins, near Minudie, Nova Scotia; Travels in North America, vol. ii. p. 180, fig. 21.

In the Joggins section many of the erect trees appear without roots; which circumstance is explained by Mr. Dawson, 1st, by the fact that in the exposed cliff the under-clays, with the roots, weather away, leaving the stumps still supported by the overlying and harder sandstone; and 2ndly, by the supposition that often the roots have been incorporated with the coal-seams.* These trunks often resemble those found erect at Dixonfold, in England; but some are decidedly *Sigillariæ*. A few of the upright trees appear to be true *Coniferæ*.

At Pictou, a hundred miles to the eastward of the Minudie coal-measures, the same group of deposits occurs, and yields a large supply of coal. In this locality there is a row of upright *Calamites*, in sandstone, all terminating downwards at the same level, where the sandstone joins a layer of coarse grey limestone with pebbles. The tops of the Calamites terminate at different heights, where the grit becomes coarser; and have not been removed by decay, but have evidently been broken sharply off, sometimes presenting at the summit a crushed appearance, like that of a hollow cylinder of paper bent at right angles. The bed of erect Calamites at St. Etienne (p. 688) is regarded by Sir C. Lyell as analogous; and he considers both localities as affording unequivocal proof of fossil trees occupying the ground on which they originally grew.† Sir C. Lyell has also described a good example of numerous upright and rooted fossil trees (*Sigillariæ*) as occurring in the coal-measures of Indiana, at Kimball's Mill, near Evansville.‡

To account for the several series of these erect trees at successive stages on the supposition that the trunks are now standing in their original position, we must suppose periodical subsidences of the land to have taken place. "It by no means follows," observes Sir C. Lyell, "that a sea four or five miles deep was filled up with sand and sediment. On the contrary, repeated subsidences, such as are required to explain the successive submergence of so many forests which grew one above the other, may have enabled this enormous accumulation of strata to have taken place in a sea of moderate depth." §

* Quart. Journ. Geol. Soc. vol. x. p. 30.

† Travels in North America, vol. ii. p. 195; Dawson, Quart. Journ. Geol. Soc. vol. vii. p. 195; and "Acadian Geology," 8vo, 1815.

‡ Second Visit to the United States, vol. ii. p. 272.

§ Travels in North America, vol. ii. p. 190.

12. Coal-shales and Vegetable Remains. — I have already stated that it is from the shales, or slaty coal of the roof, that the most abundant and illustrative examples of the plants of the carboniferous epoch are obtained; in many layers, vegetable remains occur between every lamina, the entire mass being formed of carbonized leaves and stems, closely pressed together in clay.* The carbonaceous matter is sometimes in an unconsolidated state, exhibiting the matted fibres, leaves, and stems. This condition, indicating an intermediate stage in the formation of coal, is not of unfrequent occurrence in the secondary and tertiary carbonaceous deposits, but is rare in the most ancient.†

The roof of a coal-mine, when newly exposed, displays the most interesting spectacle imaginable; leaves, branches, and stems, of the most elegant and delicate forms, being embossed on the dark shining surface.‡ The coal-mines of Bohemia, the fossil plants of which are well known, from the beautiful work of Count Sternberg,§ are stated by Dr. Buckland to be the most interesting of any he has visited,—but I will describe them in his own eloquent language. "The most elaborate imitations of living foliage upon the painted ceilings of Italian palaces bear no comparison with the beauteous profusion of extinct vegetable forms, with which the galleries of these instructive coal-mines are overhung. The roof is covered as with a canopy of gorgeous tapestry, enriched with festoons of the most graceful foliage, flung in wild irregular profusion over every portion of its surface. The effect is heightened by the contrast of the coal-black colour of these vegetables with the light ground-work of the rock to which they are attached. The spectator feels transported, as if by enchantment, into the forests of another world; he beholds trees of form and character now unknown upon the surface of the earth, presented to his senses almost in the beauty and vigour of their primeval life; their scaly stems and bending branches, with their delicate apparatus of foliage, are all spread forth before him, little impaired by the lapse of in-

* Mem. Geol. Survey, vol. i. p. 193, fig. 18.

† Silurian System, p. 100.

‡ See Mr. R. C. Taylor's notice of fossil Arborescent Ferns, Sigillaria, and other Coal-plants, exhibited in the roof and floor of a coal-seam in Dauphin County, Pennsylvania. Trans. Amer. Phil. Soc. 2 ser. vol. ix. p. 219, Philadelphia, 1843.

§ Flore du Monde Primitif.

definite ages, and bearing faithful records of extinct systems of vegetation, which began and terminated in times of which these relics are the infallible historians. Such are the grand natural herbaria wherein these most ancient remains of the vegetable kingdom are preserved in a state of integrity little short of their living perfection, under conditions of our planet which exist no more." *

13. MILLSTONE-GRIT.—The coal-measures north of the Trent are superposed on the group of coarse sandy and pebbly deposits designated by this term; but to the south these strata appear as a hard sandy rock ("Farewell-rock").

The most characteristic bed of this series is the quartzose conglomerate, termed millstone-grit, which consists of rolled fragments of quartz-rock and granite, of various sizes, from that of a pear downwards, cemented together in some instances by an argillaceous, in others by a crystalline silicious paste. Sandstones composed of the fine detritus of similar materials are associated with the grit. Water-worn fragments of shale, coal, red-sandstone, stems of plants, &c., all bearing marks of transport by currents and streams, are also often found imbedded therein. Beds of coal are occasionally interpolated in this series, and in some localities the lowermost strata consist of shales with coal-plants, and contain nodules of ironstone similar to those of the upper coal-strata, and veins of lead and copper. Satin-spar, and naphtha, petroleum, and other bituminous substances, occasionally occur in the shales of this series.

In Yorkshire the Millstone-grit is an important deposit, containing several subordinate beds of coal; and is separated from the great inferior calcareous group (known in the north of England as the *Scar-limestone*) by deposits, not less than 1000 feet thick, equivalents of the *Upper Limestone-shales* of Derbyshire, and known as the *Yoredale-rocks*, in which five series of limestone-strata, remarkable for their continuity and regular thickness, alternate with great masses of sandstone and shale, containing innumerable impressions of coal-plants, and a few seams of coal.†

In a sandstone belonging to this series, from the Hutton Roof Mine, Mr. Binney ‡ has recognised trails of Molluscs and of Annelids; and in the Millstone-grit of Tintwistle,

* Bridgewater Treatise, p. 458.

† Professor Sedgwick, "Anniversary Address," 1831, Proc. Geol. Soc. vol. i. p. 286; Phillips, "Geol. Yorkshire," and "Manual Geol." 1855.

‡ Trans. Phil. Lit. Soc. Manchester, 2nd ser. vol. x. p. 181.

Cheshire, the same indefatigable explorer of the Coal-formations of Central England has discovered* fine tracks of a probably reptilian quadruped, similar to, but of much larger proportions than even that which has left on the Permian sandstones of Corncockle Muir the impressions referred to *Chelichnus Titan* by Sir W. Jardine. Prof. Harkness also has recognised Annelid tracks in the Millstone-grit† (Ireland).

14. Carboniferous or Mountain Limestone.—Beneath the Millstone-grit and Upper Limestone-shale, and indeed intimately connected with the latter, is the great calcareous member of the lower portion of the Carboniferous system. This is an extensive assemblage of calcareous strata, composed for the most part of subcrystalline grey limestone, disposed in beds of considerable thickness; the strata through a depth of many hundred feet being separated only by very thin clay-partings. Shales and grits are intercalated in certain localities; and in some countries important beds of coal are situated in this division of the system. Layers and nodules of chert occasionally traverse the limestones, like the flints in chalk.

The term *Mountain-limestone*, applied to these calcareous rocks, has originated from their often forming elevated mountain-chains, as in Derbyshire, Yorkshire, Somersetshire, &c., giving rise to scenery which equals, if not surpasses, in picturesque beauty that of any other part of England. I need but mention the vale of the Avon at Clifton, Matlockdale, Dovedale, the escarpments that overhang the Wye near Chepstow, &c. The magnificent gorge of the Avon at Clifton is flanked by an uninterrupted succession of mural precipices, known by the name of St. Vincent's Rocks, and presents an unrivalled natural section of the Carboniferous limestone. The calcareous beds rest on strata of the Devonian series, which may be seen on both sides of the river, near Cook's Folly, extending on the south under Leigh-down and Weston-down.‡

* Quart. Journ. Geol. Soc. vol. xii. p. 350.

† Edin. New Phil. Journ. new series, vol. i. p. 278.

‡ Descriptions and sections of these rocks have been made by Dr.

This series of strata is also remarkable for the deep chasms and fissures by which the rocks are traversed; the principal caverns of this country being situated in them; those of Derbyshire, Yorkshire, Somersetshire, &c., are well known. Swallow-holes and subterraneous rivers are likewise frequent throughout the districts formed by these deposits.

The mountain-limestone is largely developed over the central and northern parts of England, and the south-west of Scotland: and it is the predominant rock throughout the greater part of Ireland. In Somersetshire, Gloucestershire, Shropshire, North and South Wales, and Derbyshire, it constitutes an almost entirely calcareous mass, interposed between the Devonian group below (or, where that is wanting, the more ancient Silurian rocks) and the upper shales, grits, and coal above. In Cumberland, and Westmoreland, &c., it appears as an elevated belt, which partly surrounds the Cumbrian slate-mountains, and forms, on the west, a ridge nearly three thousand feet in height.

In Northumberland the mountain-limestone, modified by intercalated shales and coal-beds, and associated with the overlying millstone-grit, occupies large areas, and constitutes ranges of hills of considerable elevation; the geographical features strongly contrasting with those of the adjacent country on the south, which consists of the upper coal-bearing strata, spread out in a plain of great extent.

In Derbyshire the grand physical features of the country are produced by the mountain-limestone, which rises into crags or peaks, and hills, presenting bold precipitous escarpments, and produces the wildest and most picturesque scenery. Professor Phillips estimates the thickness of the lower division of limestones, with shale-partings, in Derbyshire at 750 feet; the alternations of shale, sandstone, limestone, and ironstone, which surmount the former, at 500 feet; and the cappings of millstone-grit which form the summits of the hills, at 360 feet.

The Carboniferous Limestone, though some of the beds are destitute of fossils, is for the most part largely made up of corals, crinoids, shells, &c.; these often form three-fourths of the mass. Of the 1900 feet thickness of Mountain-limestone in South Wales, the lower half may be said to be made up of *Crinoidea* and *Strophomenæ*, and the upper portion of

Bright (Geol. Trans. vol. iv. p. 193); Mr. Cumberland (*ibid.* vol. v. p. 95); Buckland and Conybeare (*ibid.* 2 ser. vol. i. p. 210); De la Beche and Williams, Mem. Geol. Surv. vol. i. p. 113; Lonsdale, Murchison's Sil. Syst. p. 158. See also Excursions to Clifton, Matlock, and Crich Hill; Medals of Creation, vol. ii. pp. 864, 867, 880.

corals (De la Beche and Phillips). We reserve a more particular notice of these organic remains for a subsequent part of this Lecture. The Derbyshire encrinital marbles (see p. 660), and the coral-marbles of St. Vincent's rocks, near Clifton, are well-known examples of the finer compact varieties of these calcareous deposits.

In the Bristol and Mendip district, some beds of this great limestone have an oolitic structure,* the spherules containing grains of sand, water-worn fragments of shells and other organic substances, or the little shells of foraminifera.

The chert, where interpolated among the crinoideal remains, contains beautiful casts and impressions of the stems and ossicula, and also of the associated shells, in consequence of the silicious matter, which surrounded and penetrated these bodies, having resisted the chemical action that subsequently destroyed the calcareous structure of the originals.†

15. DERBYSHIRE LEAD-MINES.—It is in the mountain-limestone that the principal British lead-mines are situated, namely, those of Somerset, Derbyshire, York, Flint, Durham, and Northumberland. In Derbyshire the metal occurs in numerous veins which traverse the strata, and extend in some instances into the *toad-stone*,—a volcanic rock which we shall describe in the sequel. The perpendicular veins (*rake-veins*) are from two to forty feet wide; and there are chasms or hollows in the rock, several hundred feet in width, which also contain metallic ores and spars. Manganese, copper, zinc, and iron are found in the limestone; but the predominating metalliferous ore is the sulphide of lead, or galena. This substance is of a bluish-grey colour, and often occurs in

* This is not the oldest instance of the occurrence of the oolitic structure in rocks. It is present in some parts of the Bala limestone. As more modern instances, may be mentioned oolitic beds in the Zechstein of the Permian, and the Muschelkalk of the Trias.

† See the pulley-stone, *Lign.* 152, *fig.* 1, which is a silicious cast of an encrinital column.

cubic and octahedral crystals; it is also disposed in thin layers, as well as in veins. It is accompanied by fluor-spar, calc-spar, sulphate and carbonate of barytes, iron-pyrites, &c. The variety termed specular galena, or *slickensides*, is a thin coating of lead on the sides of the veins, and appears to have arisen from one wall of the fissure having slipped along the face of the other, so as to give it a polished or *slicken* surface.

The beautiful mineral known by the names of *fluor-spar*, *chlorophane*, and *Derbyshire spar*, and provincially called *Blue-John* and *Bull-beef*, so much in request for vases and other ornamental purposes, is a fluate of lime,* found in the state of veins, and in large irregular masses from three inches to a foot in thickness, in the Odin mines, near Castleton, in Cornwall, and elsewhere.

The structure of the country around Matlock and the principal metalliferous districts of Derbyshire are so fully described in various works, that the present brief notice of the manner in which the mineral and metallic productions occur will suffice. The chasms in the limestone exposed in some of the quarries are often more or less incrusted with minerals and spars, and exemplify the mode in which the rich metallic veins of lead are distributed in the interior of the mountains. A fissure which I observed in a quarry in Crich Hill will serve as an illustration. A layer of the dark blue-grey sulphide of lead, or *galena*, was spread over the surface of the limestone that formed the walls of the fissure, upon this was deposited a layer of white baryt-spar, and on the latter was a coating of cubic crystals of fluor-spar of a light-blue colour. Usually the fissure is filled up by alternating layers of crystalline veinstones enclosing a central vein or "rib" of galena.

16. CARBONIFEROUS ROCKS OF DEVONSHIRE.—The rapid

* This appears to have been the enigmatical substance of which the almost priceless "Myrrhine vases" of ancient Rome consisted. (Fraser's Mag.)

sketch above given of the principal features of the three groups of strata composing the Carboniferous system affords a general idea of the prevailing characters of this important formation. There is, however, an extensive series of rocks which belong to this epoch, but occur under conditions that have rendered their relations somewhat obscure, and occasioned them to be classed with the more ancient beds, until the investigations of Professor Sedgwick and Sir R. I. Murchison demonstrated their true position in the chronological

Fig. 1.

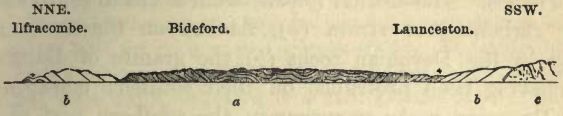


Fig. 2.

LIGN. 159.—SECTIONS OF THE STRATA OF DEVONSHIRE.

Fig. 1. Section from NNE. to SSW. showing the carboniferous strata (*a*) in the centre, resting on each side on schists and sandstones of the Devonian series (*b*, *b*); a protrusion of granite (*c*) occurring on the SSW.

— 2. Section from north to south: the carboniferous beds (*a*) repose on Devonian strata on the north (*b*); while towards the south the granite of Dartmoor has been protruded (*c*); the Devonian series (*b*) re-appears in the southern part of the county, terminated by a band of micaceous schists (*d*).

a, Culmiferous rocks of Devonshire: grits, schists, culm, and Posidononomya-limestone.

b, Devonian rocks: Clymenia-limestone and schists, sandstones, Stringocephalus-limestone and schists, conglomerates, sandstones, and lowest schists.

c, Granite.

d, Micaceous schists; altered or metamorphosed strata.

arrangement of the British strata.* This group consists of shales, limestone, and slaty coal (provincially called *culm*), constituting a trough of carboniferous deposits super-im-

* Geol. Transact. 2 ser. vol. v. p. 633, &c.; Report British Assoc. 1836, sect. p. 96; Phil. Mag. vol. xiv. p. 241, &c.; Edinb. New Phil Journ. vol. xliii. p. 33; Quart. Journ. Geol. Soc. vol. viii. p. 8, &c.

posed on "Devonian" strata, but much dislocated and altered in character by intrusions of granitic rocks.

The culmiferous deposits of Devonshire were once connected with the coal-formation of South Wales, on the north side of the Bristol Channel: the fossil vegetables which they contain appear to be identical with those of the coal-basin of South Wales. In the section, *fig.* 1, through Devonshire from NNE. to SSW. the culmiferous beds (*a*) are seen to occupy a trough, and to repose on each side on the schists and calcareous sandstones (*b*, *b*) of the *Devonian* or Old Red series. The section (*fig.* 2) from north to south shows the carboniferous strata (*a*), flanked on the north side only by the Devonian rocks (*b*), the granite of Dartmoor (*c*) having been protruded on their southern edge; while the Devonian rocks re-appear in the southern part of the county, terminated by a band of micaceo-chloritic schists, which are parallel to the great disturbing axis of Cornwall and Devon, and are probably metamorphosed sedimentary deposits.*

17. TRAP-ROCKS AND TRAP-DYKES OF THE CARBONIFEROUS SERIES.—The coal and its associated strata everywhere exhibit proofs of the violent subterraneous movements which they have undergone since their original deposition; and but few coal-fields are free from extensive faults and dislocations, by which the beds have been broken up and thrown into different levels and positions. The entire group is also often traversed by veins and dykes of intruded volcanic rocks; generally consisting of the hard, dark-green, fine-grained stone, called *trap*.

In Yorkshire there is a trap-dyke of prodigious extent and thickness, named the *Whin-sill*, which traverses the coal-measures, red sandstones,

* Besides the above-quoted works by Sedgwick and Murchison on the Culmiferous beds of Devonshire, the reader should also consult De la Beche's "Report on Cornwall, Devon, and West Somerset," Phillips's "Palæozoic Fossils of Devon," &c., and the first vol. of the "Mem. Geol. Survey;" and Sir R. Murchison's "Siluria."

and lias, and passes from High Teesdale to the confines of the eastern coast; a distance of upwards of sixty miles.

In Derbyshire, a trap-rock, in many parts amygdaloidal, and which, from being mottled with green and yellow, has received from the miners the name of *toad-stone*, is interpolated between the beds of mountain-limestone of that country, under circumstances of considerable interest.*

These phenomena can nowhere be studied with more advantage than in the neighbourhood of Matlock, which is a region of carboniferous limestone, broken up and traversed by volcanic rocks.

The trap-rock of Derbyshire was evidently erupted in a state of fusion from some very deep-seated source of intense heat, and intruded between the limestone-beds in three principal currents, now appearing as alternations of trap-rock with sedimentary strata, but which, there is every reason to believe, sprung from one common source, and are lateral protrusions from the great mass of igneous matter. The *toadstone* is a hard rock, consisting of small nodules of white and yellow calcareous spar and green earth, imbedded in a dark greenish paste of basalt. Sometimes the nodules are decomposed, and the stone is then vesicular or cellular, resembling porous lava. The thickness of each of the three distinct beds of this ancient subterranean lava-current interpolated in the mountain-limestone of this district varies from sixty to eighty feet. In some instances, dykes of toadstone traverse the metalliferous veins, and a manifest alteration is then observable in the nature of the latter.†

In some places the elevatory movements have torn the rocks asunder; in others the strata have partially resisted the expansive effect of the erupted lava, and are now in a dome-shaped or arched position, and more or less bent and folded.

Crich Hill, near Matlock affords a highly interesting illustration of this effect of igneous action. It is a dome-shaped hill of mountain-limestone, 800 feet high, consisting of arched strata, enfolding a central mass of trap. This dome of limestone has been forced up through the once superincumbent strata of millstone-grit, which now form a broken and highly inclined wall around it. Such is Crich Hill, a stupendous monu-

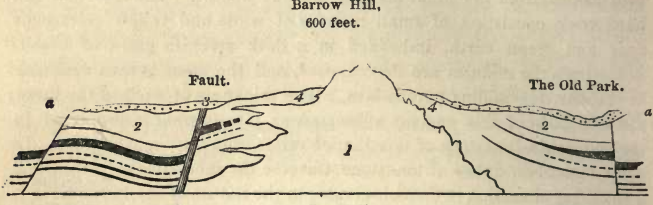
* See Mr. W. Hopkins's "Remarks on Mr. Farey's Account of the Stratification of the Limestone District of Derbyshire," Phil. Mag. 3rd ser. vol. v. p. 121.

† In the cavern at the base of the High Tor in Matlock Dale, a bed of toadstone is seen on the floor, beneath the limestone-strata of which the cliff is composed, and may be traced across the river to the opposite escarpment of Masson's Hill, where it is exposed on the road-side. See Medals of Creation, vol. ii. p. 876.

ment of one of the past revolutions of the globe,—with its arches of rifted rock teeming with mineral veins, and resting on a central mound of molten rock now cooled down into an amorphous mass of compact basalt.*

A dyke of the volcanic rock called green-stone, in some places eighteen yards wide, and which has been traced nearly seventy miles, traverses the Newcastle coal-measures on Cockfield-fell. The coal at the distance of fifty yards from the dyke is altered in its character, and near its contact with the erupted mass is reduced to half-burnt cinder and sooty coaly matter. Wherever trap traverses coal-deposits, more or less change is always observable in the carbonaceous materials.

18. FAULTS IN THE COAL-MEASURES.—In illustration of the displacements called faults, in carboniferous strata,



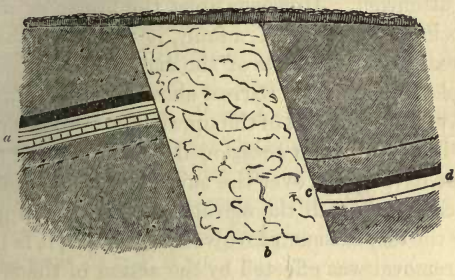
LIGN. 160.—ERUPTED TRAP-ROCK, IN THE DUDLEY COAL-FIELD.
(*Sir R. I. Murchison's Sil. Syst. pl. 37, fig. 1.*)

a, *a*, Alluvial soil.
1. Erupted Trap-rock.
2, 2. Coal-measures.
3. Barrow Fault: upcast of 90 yards.
4, 4. Coal, charred and altered from contact with the Trap.

I shall select a remarkable one that occurs in the Dudley Coal-field, near Barrow Hill (*Lign.* 160). The central mass of erupted trap that occasioned the dislocation rises to the surface, and forms the summit of Barrow Hill, which has an elevation of about 600 feet. The displacements of the strata on each side of the volcanic rock have produced two lines of fault: and the coal in contact with the igneous rock, as is usual under such circumstances, is charred, and deprived of its bituminous quality.

* See Medals of Creation, p. 890.

In the principal fault, the coal-beds are rent asunder to an extent of 140 yards; and in the part represented in the sketch (*Lign.* 161), the erupted mass (*b*) has upcast the strata on the south-east ninety yards (*a*); the sides of the fissure being inclined from eighty to ninety degrees; thus the group of strata, *a*, *d*, which were originally continuous and



LIGN. 161.—SECTION OF A FAULT IN THE DUDLEY COAL-FIELD, NEAR BARROW HILL. (*Sil. Syst.* p. 504.)

a, *d*, Carboniferous strata; the black line denotes the main bed of coal; *b*, Intruded Trap; *c*, the upward twist of the bed of coal *d*, where in contact with the Trap-dike.

horizontal, have been separated, and the edges of the lower portion twisted upwards, as is shown at *c*, by the intruded trap. These carboniferous strata are superimposed on red conglomerate. We shall have again occasion to notice the displacements in the Dudley Coal-field, when treating of the trappean ridges of that part of England.

The faults and dislocations of the strata are so numerous in many coal-fields, that they have been very aptly compared by Dr. Buckland to a fractured sheet of ice:—"If we suppose a thick sheet of ice to be broken into fragments of irregular area, and these fragments again united after receiving a slight degree of irregular inclination to the plane of the original sheet, the reunited fragments of ice will represent the appearance of the broken masses or sheets of coal-measures. The intervening por-

tions of more recent ice, by which they are held together, represent the clay and rubbish that fill the faults, and form the partition-walls that insulate these adjacent portions of strata, which were originally formed like the sheet of ice, in one continuous plane."*

There is a circumstance connected with the upheaval and disruption of the carboniferous strata, and which is also observable in other loosely aggregated deposits, that demands attention. However great the uprise or downcast of the rocks on one side of a fault, it is seldom that there are any external indications of the displacement visible; as for example in the fault of Barrow above sketched (*Ligns.* 160 and 161).† The removal of the upraised masses has possibly, in some instances, been occasioned by debacles or floods of water that have swept over the surface of the country; but in those cases in which the elevated strata were of great extent, and the displacement involved large areas, it is probable that the removal was effected by the action of the sea, when the rocks were first dislocated and forced upwards, and before they emerged above the waters. In other instances, the disintegration may have taken place during their gradual elevation, in like manner as the removal of the Chalk, and the denudation of the underlying Wealden of the south-east of England, were produced. (See above, vol. i. p. 371.)

19. GEOGRAPHICAL DISTRIBUTION OF THE COAL-MEASURES.—Although the geological map (*Plate* I. p. 474) is on a small scale, it will serve to convey a general idea of the geographical position of the areas occupied by the Carboniferous strata of England. The principal coal-basins are those of Somersetshire, Gloucestershire, North and South Wales,

* Bridgewater Treatise, p. 543.

† Mr. Bakewell has treated this subject with great ability: see chap. ix. "On the general removal and disappearance of the coal-strata, raised by faults above the surface of the ground."—*Introduction to Geology*, 5th edit. p. 200.

Dudley, Shropshire, Leicestershire, Lancashire, Nottingham, Derbyshire, Yorkshire, Cumberland, Durham, and Newcastle. In Scotland, we have those of the Forth and Clyde. The central districts of Ireland have extensive coal-deposits; but by far the greater part of the coal of Ireland is anthracitic: there are several coal-basins exclusively of this mineral in five or six counties in the south of the Island.

On the Continent, coal, with limestones and conglomerates, in some instances resembling, in others differing from, the English strata, occur in France, near Boulogne,* Mons, and St. Etienne; in Belgium, at Namur and Liege;† in Germany, Silesia, Moravia, Poland, and in the Carpathian Mountains. The Mountain-limestone tract along the Meuse, in the Netherlands, resembles that of Derbyshire and Monmouthshire, and is of the same age; and the scenery to which it gives rise will remind the English traveller of the banks of the Derwent or the Wye.

In Germany‡ two great coal-bearing series of rocks of palæozoic age are recognised. The lower of these is the "Younger Granwacke" of the Germans, called also the "Flœtzleerer Sandstein," and is equivalent probably to the millstone-grit, the culm series of Devon, and some part of the Scottish coal-measures. The upper series often rests unconformable on the other, and is known as the "Steinkohlen-formation," and represents the English coal-fields. The Mountain-limestone is termed "Berg-kalk" in Germany, and is divisible into, 1st, schists, full of *Posidonomyæ*, such as are found also in Devonshire and South Scotland; 2nd, Productus-limestones; 3rd, silicious flagstones, or "Kieselschiefer."

* See Mr. Godwin-Austen's Memoirs, Quart. Journ. Geol. Soc., vol. ii. p. 1, and vol. ix. p. 231.

† See Journ. Geol. Soc., vol. xii. pp. 47 and 252.

‡ See Geinitz's "Steinkohlen-Format. Sachsen;" and Murchison and Morris, "On the Palæozoic Rocks of Thuringia," &c., Quart. Geol. Journ. vol. xi.

In many parts of France and Germany there are isolated patches of coal-strata, entirely free from marine fossils, and reposing on granite and other hypogene rocks: they are, however, confined to small areas: as in the Department of the Loire, at Brassac in Silesia, and many other places. All these deposits appear to have been formed in lakes, existing on land-areas skirted by the sea in which the Mountain-limestone was deposited.*

In Central France, the rocks that constitute the eastern boundary of the Limagne d'Auvergne are referable to the Carboniferous period, and present phenomena of a highly interesting character, which were first pointed out by Sir R. Murchison in a memoir "On the Slaty Rocks of the Sichon." †

The mineral structure of the schists of the Sichon, their purple, plum-coloured exterior, and their fracture, combined with the aspect of the sandstones, grits, and conglomerates, give them a character from which few geologists would hesitate to assign them to the greywacke, or most ancient Silurian or Cambrian deposits. But Sir R. Murchison, in 1851, obtained fossils ‡ which prove that these rocks belong to the Carboniferous series: the intrusive porphyries of this tract having been erupted after their deposition. Many of the beds of the coal-field of St. Eloy, near Montaigne, are made up of the detritus of still older schists and their quartz veins. Sir R. Murchison could not positively determine whether this coal-tract, as well as other numerous little coal-deposits that extend along the western side of the Mont Dor into the Cantal, are not of the same date as the carboniferous schists of the Sichon; but he is inclined to think them an upper member of the same group. At all events, the highly dislocated positions of the former, and the manner in which they are wedged in among more ancient rocks, indicate that the great porphyritic eruptions above alluded to took place subsequently to their accumulation.

From this occurrence of Mountain-limestone fossils in strata of such

* For an admirable exposition of the relative positions of land and water during the coal-period, see Mr. Godwin-Austen's Memoir, in the Quart. Journ. Geol. Soc. vol. ix. p. 57, &c. See also "Sil. Syst." p. 148.

† Journ. Geol. Soc., vol. vii. p. 5, &c.

‡ Chonetes, Phillipsia, Orthis, Productus, &c., of Carboniferous species.

an antique crystalline aspect, and which are highly dislocated and inclined, and are overlaid unconformably by certain coal-fields of France, it is evident that there must have been a powerful disruption of the older members of the Carboniferous—the Mountain-limestone with its shales and sandstones—before the superimposed coal-bearing deposits were accumulated. This fact is of the highest importance in a palæontological point of view, since it proves that the distribution of animal life and the chronology of ancient races do not necessarily accord with the former physical revolutions of the earth's surface. This phenomenon is in accordance with that complete and absolute change in the zoology of the Permian and the Trias, although these deposits present scarcely any evidence of mutual unconformability. On the other hand, whilst many of the Permian *Producti* approach closely to Carboniferous types, there has been in many countries a great break between these two latter deposits. In Britain there has been no *general* severance between the lower and upper members of the Carboniferous series, and hence we possess a very full and copious development of all its middle portion.*

In Silesia and Poland the coal-measures are interstratified with shales and sandstones which overlie the Mountain-limestone, as in England and Belgium; but in the Russian Empire the productive coal-beds are situated in the Mountain-limestone, and are unquestionably fluvio-marine; for through a thickness of eight hundred feet, limestones, grits, and shales, abounding in marine shells, alternate with beds of coal, accumulated apparently by driftage.

In the coal-field of Tudela in Asturia, Spain, there are between twenty and thirty seams of coal. The beds are thrown up into a nearly vertical position, at an angle of about 80° with the horizon. The strata constitute a hill about 400 feet high, and stretching from east to west a mile, and a half from north to south.

20. Carboniferous system of North America.—In North America, the Carboniferous system is largely developed, and has been ably illustrated by Professors Silliman, Eaton, Hitchcock, Rogers, Owen, and other geologists. The stone-coal, or *Anthracite*, of Pennsylvania is associated

* Op. cit. p. 8.

with conglomerates, sandstones, and argillaceous shale; and the conglomerates are composed of quartz-pebbles like those of our Old Red Sandstone. Deposits of anthracite exist in Worcester and in Rhode Island, of which an admirable account has been published by Professor Silliman.

Extensive coal-fields are found to the west of the Alleghany Mountains, towards the Mississippi; and the base of the whole extent of the plain of that mighty river appears to be Carboniferous Limestone, the strata of which rest against the Alleghany Mountains on the east, underlie the sand-plains on the west, and, with the lower palæozoic rocks, are upturned on the flanks of the Rocky Mountains at Fort Laramie.* The uppermost layer of the Mountain-limestone supports strata of bituminous coal and shale. Iron-stone abounds in these deposits; and mines of lead occur over a district of two hundred square miles, in the States of Missouri and Illinois.† The principal coal-fields in the United States are the Appalachian, the Illinois, the Arkansas, and the Michigan; the Appalachian, with a computed superficial area of 63,000 square miles, is 726 miles long, and in many parts 180 wide, exclusive of detached anthracitic basins to the eastward: the Great Western, or Illinois,‡ is much more extensive, and has an area as large as England.

The Appalachian coal-field, before its original limits were reduced by denudation, is computed to have been 900 miles long and 200 wide. The thickness of the Carboniferous strata in Virginia and Western Pennsylvania exceeds 3000 feet.§ A large portion of the coal is in the state of *anthracite*, or stone-coal, generally resulting from the influence of subterranean high temperature at former periods. For the most part, the bituminous coal is that which is farthest re-

* Marcou's Geol. Map. † Smart's Travels in the United States.

‡ Dale Owen's Geol. Survey of Wisconsin, Iowa, &c.; Lyell and Hall Report on the New York Exhibition.

§ Professor H. D. Rogers' Address, May, 1844.

moved from the axis of the greatest disturbance, and where the strata have suffered the last displacement. In the coal-fields where the boldest flexures of the Appalachian chain occur, and the strata have actually been overturned, as near Pottsville, the coal is invariably changed into anthracite.*

The Carboniferous system of the United States presents all the essential characters of that of England. The coal-fields are rich in iron-ores; and the same prevalence of *Stigmariæ* in the underclay of the coal-beds occurs as constantly as in the European coal-fields. Thus in the coal-mines of Blossberg, Pennsylvania, the underclays contain Stigmariæ with their rootlets extending in all directions, as in the underclays of the Welsh coal-measures 3000 miles distant.† At Pottsville, where the coal-strata are vertical and worked in the open air, the same phenomenon appears. Several of the coal-seams, from eight to ten feet thick, having been removed, a void space was left, and in the wall on one side, corresponding to the roof, were shales full of ferns, lepidodendra, calamites, &c.; while the other side of the trench was formed of the underclay, abounding in Stigmariæ. These phenomena lead to conclusions respecting the origin of coal from plants not drifted, but growing on the spot. But throughout some of the beds of underclay leaves of fern are plentifully dispersed, though the Stigmariæ are apparently imbedded in their natural position.‡ Limestone of marine origin is more common in the American coal-fields than in those of England; and at Frostburg § a bed of black bituminous shale, ten or twelve feet thick, full of marine shells, is interstratified with the coal.

The Mountain-limestone is thin under the Appalachian or Alleghany coal-field; and in Pennsylvania it is represented by red shale and sandstone, with thin limestones, and yielding valuable carbonates of iron; it is thicker to the south and west, sometimes dolomitic, and is occasionally (Southern Illinois) rich with lead-ores.

In Nova Scotia and Cape Breton, the Carboniferous formation is composed of (1.) an upper and (2.) a lower series

* See the section of the country between the Atlantic and the Mississippi, through the Alleghanies, in Lyell's Travels in North America, vol. i. p. 92: and the admirable geological map of the United States, by Prof. H. D. Rogers, in Keith Johnson's "Physical Atlas."

† Lyell, ibid. pp. 62 and 84. ‡ Ibid. vol. ii. p. 18. § Ibid. p. 19.

of coal-measures, and (3.) the Carboniferous Limestone, associated with gypsum, marls, and sandstones.*

The Carboniferous Limestone has also been recognised in the Arctic Regions,† South America,‡ Northern India,§ and probably in Australia.‖

Coal of New Zealand.—The coal found in the north and middle Islands of New Zealand is lignite, more or less compact, and referable to tertiary formations, according to the observations of Dr. Dieffenbach, Mr. Walter Mantell, Dr. C. Forbes, and others. But, according to a communication from Mr. William Lyon to the author, coal of a more ancient period exists about thirty miles from Christchurch, in the valley of the Selwyn. The Canterbury district, from Timaru to Waipara, is in many places bordered by a series of low undulating downs, resting upon the rugged ancient rocks which form the vast boundary-line of the settlement. It is in that portion of these downs known as the Malvern Hills that the coal-formation occurs. It consists of the usual series of limestones, sandstones, clays more or less indurated and laminated, bituminous shales, seams of coal and clay, ironstone, &c., which usually constitute the coal-measures. The limestone is the highest bed seen cropping out; it is fossiliferous, of a superior quality, and at least sixty feet in thickness: separated from this by sandstones and shales, lies the main seam of coal; the first seam is four; the one beneath, six feet in thickness. The associated rocks contain seams of clay-ironstone, one of them abounding in fresh-water shells—*uniones* (?). The laminated clays and shales contain impressions of stems and leaves

* See Prof. Dawson's "Acadian Geology," 1855.

† Sir E. Belcher, "Arctic Voyage," 1855; Appendix.

‡ A. D'Orbigny, Voyage dans l'Amér. Mérid. vol. iii. p. 231.

§ Dr. A. Fleming, Quart. Journ. Geol. Soc. vol. ix. p. 293.

‖ See the Works of Strzelecki, Darwin, Jukes, M'Coy, Clarke, Stutchbury, &c.

of ferns, apparently of the genera *Pecopteris* and *Sphenopteris*.

21. ORGANIC REMAINS OF THE CARBONIFEROUS SYSTEM.—The fossils entombed in these deposits comprise numerous genera and species. The animal remains are principally found in the calcareous and arenaceous strata, and are referable to zoophyta, radiaria, crustacea, mollusca, and fishes: and numerous undoubted relics of the reptilian order have been discovered. The vegetable fossils, besides constituting the entire mass of the coal, anthracite, &c., are thickly interspersed in the shales, grits, and other intervening deposits. The shells in the shales of the coal-measures are generally such as are now represented by species living in fresh or estuarine waters; that is, forms related to the Unio, Mytilus, &c.: but there are intercalated beds of marine shells in some localities; as, for example, in Coalbrook Dale. In the northward extension of the Mountain-limestone of Britain, there are intercalations of fresh-water deposits among the limestones and shales which are full of marine shells; and some of the carboniferous deposits of Linlithgowshire are said to be traceable from the fresh-water into the marine condition.*

But the grand features of the Carboniferous system are the immense accumulations of the early vegetation of our globe, presenting to us, in the most legible and striking characters, the peculiar flora of the remote epoch in which these deposits were produced. To obtain any satisfactory results from an examination of these remains, some know-

* Mr. A. Taylor exhibited and explained before the Royal Physical Society of Edinburgh, January 28, 1857, a section in the Bathgate Hills, from Dechmont Laws to Balbardie House, in which a limestone, containing fresh-water fossils, and equivalent to the one worked at Burdie House, is seen gradually to merge into another limestone, containing marine fossils, which is usually recognised as the lowest bed of the Carboniferous series.—*Edinb. New Phil. Journ.* new ser. vol. vi. p. 165.

ledge of the internal structure of vegetables is requisite; for in a fossil state many of the external characters are, for the most part, so imperfect or obliterated, as to afford but obscure indications of the nature of the original. As in our investigations of the fossil remains of animals we availed ourselves of the principles of comparative anatomy to reconstruct those extinct forms of being, in like manner we must now call to our aid that branch of science which treats of vegetable organization; we shall thus be enabled to restore anew the forests of extinct tree-ferns and coniferæ, the jungles of calamites, and all the luxuriant vegetation which flourished during the Carboniferous epoch. I must, however, restrict myself to a brief enunciation of a few leading botanical principles.* The works of Adolphe Brongniart † and of Lindley and Hutton,‡ together with those of Corda, Unger, Goeppert, Hooker, Henslow, Balfour, and Henfrey, should be consulted by those who would pursue this attractive department of natural history.

22. ORGANIZATION OF VEGETABLES. — In the previous discourse, the complex organization of the higher orders of animal existence was remarked; the structure of vegetables, on the contrary, presents a remarkable simplicity. While in most animals each separate function is effected by an organ of peculiar construction, in plants a few tissues, variously modified, constitute the mechanism by which all the vegetable functions are performed. The section of any living plant shows that its intimate structure is made up of cells or vessels (see also p. 609). § This organization is dif-

* See Medals of Creation, vol. i. chapters 4, 5, and 6.

† Histoire des Végétaux Fossiles, ou Recherches Botaniques et Géologiques, &c., par M. Adolphe Brongniart.

‡ The Fossil Flora of Great Britain, by Dr. Lindley and W. Hutton.

§ Every vegetable cell is the result of the development of a minute granular body or nucleus, on the surface of which a transparent vesicle arises, spreading out so as to form a cell, which, afterwards expanding

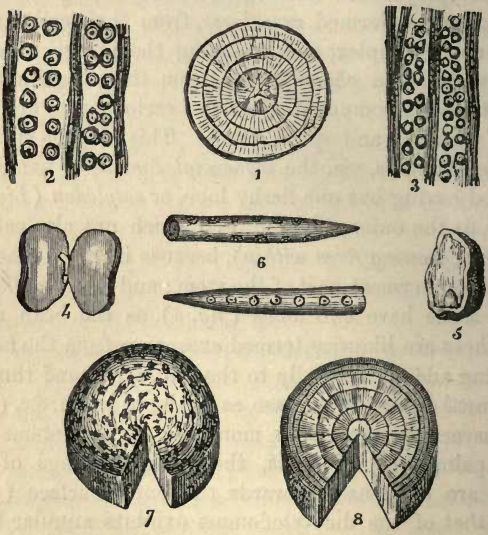
ferently arranged in the grand classes of the vegetable kingdom.* In the most simple group, the *cellulares*, called also the *acotyledones*, from the absence of *cotyledons*, or seed-lobes, the tissue is wholly cellular, the cells being nearly of equal size and consistence; mosses, lichens, sea-weeds, fungi, &c., are examples. These plants have no flowers, and hence are named *cryptogamia*. The vegetables belonging to the other great class are termed *vasculares*, from their cellular tissue being more complex, and assuming the structure of tubes and vessels; and *phanerogamic*, from their bearing flowers. Their tissue is composed of cells of various sizes and forms, and of straight and spiral tubes. This class is subdivided into two families, viz. the *monocotyledonous*, so named from the seed having but one fleshy lobe, or *cotyledon* (*Lign.* 162, *fig.* 5), as the onion, lily, &c., and which are also called *endogenous* (*growing from within*), because increase takes place from the innermost part of the stem; and the *dicotyledonous*, whose seeds have two lobes (*fig.* 4), as the bean, almond, &c.; these are likewise termed *exogenous*, from the new matter being added externally to the old layers, and thus forming annual circles of increase, as in the oak, elm, &c. (*fig.* 8). A transverse section of the monocotyledonous stems (as the cane, palm, &c.) presents, therefore, openings of tubes, which are condensed towards the outer surface (*fig.* 7); while that of the dicotyledonous exhibits annular lines of growth, with diverging rays and a central pith (*fig.* 8); the

more in particular parts, acquires the peculiar form which characterizes the texture to be fabricated. The chemical composition of this elementary structure is identical with starch. In every vegetable, whether the oak or the fungus, this primitive membrane presents the same character; and all the beautiful and apparently complicated tissues of vegetables are but modifications and expansions of these simple elementary nucleated vesicles.

* See Pict. Atlas, Supplem. Notes, p. 175, &c., for a sketch of the history of Fossil Botany, with an outline of Ad. Brongniart's Classification of Fossil Plants, derived from the "Mém. Mus. Nat. Hist." 1822.

latter character is of peculiar importance, because all the other classes are destitute of a central cellular column.

In some groups of dicotyledonous trees the elongated cells, or wood-fibres, are studded with minute pits or transparent spots (*fig.* 6); and this is particularly the case in the *Coniferæ*, or *cone-bearing* trees; so called from the fruit being in



LIGN. 162.—ILLUSTRATIONS OF VEGETABLE STRUCTURE.

Fig. 1. Cross-section of a coniferous tree, showing the concentric and radiated structure.
2. Longitudinal section of a fragment of pine-wood, highly magnified to exhibit the spotted fibres.
3. Longitudinal section of two fibres of an Araucaria, highly magnified to show the spots arranged alternately.
4. A dicotyledonous seed split open; the germ is seen in the middle.
5. Section of a monocotyledonous seed, with the germ below.
6. Dotted fibres of coniferous wood.
7. Transverse section of a monocotyledonous stem.
8. Transverse section of a dicotyledonous tree, showing concentric circles, medullary rays, and the central pith.

the form of a cone, as in the pine, fir, &c. Transverse sections of the stems of these trees show the concentric layers,

or annular rings, and radiated structure peculiar to the dicotyledonous class. All the trees of this order secrete resin, have branched trunks, and linear, rigid, entire leaves: species are found in the coldest as well as in the hottest regions. In this magnified view of a slice of the common fir (*fig.* 2), the pits are seen to be arranged in double parallel lines. In a remarkable family of pines, the *Araucariæ*, these little spots are placed alternately, and sometimes in triple rows. The *Araucaria* is a native of and peculiar to Norfolk Island, in the South Pacific. This small island, which is only about fifteen miles in circumference, presents a scene of the most luxuriant vegetation, and abounds with this particular group of pines, some of which attain a height of two hundred feet, and a circumference of thirty.

In the Royal Botanic Garden of the University of Breslau is a fossil stem of the *Pinites protolarix* (from the Brown-coal of Laasan in Silesia), which is thirty-six feet in circumference, which is reputed to have possessed between 4000 and 5000 annual rings! (Gœppert. See p. 671). The living *Wellingtonia* or *Sequoia gigantea* has a height of three hundred feet, and a diameter of from twenty to thirty feet.

Even in the foliage of the different families of plants, there are such obvious distinctive characters that the botanist can often from a mere fragment of a leaf detect the dicotyledonous structure in the reticulated nervation of a leaf, as in that of the oak; and the monocotyledonous, in the smooth parallel veins in that of the lily. The application of these principles to the investigation of the fossil remains of vegetables we may now consider.

23. Climate and Seasons indicated by Fossil Wood.—In the course of these Lectures, it has been demonstrated how, by a knowledge of comparative anatomy, the form, structure, and economy of beings long since obliterated from the face of the earth may with certainty be determined; in like manner, by the aid derived from a

few botanical principles, we may not only discover the form and character of vegetables of which but the faintest vestiges remain, but also point out important inferences relating to the state of the earth, the nature of the climate, and even of the seasons which prevailed at the periods when those plants flourished. Mr. Babbage has admirably exemplified the inductive process by which such results may be obtained:—

"We have seen that dicotyledonous trees increase in size by the deposition of an additional layer annually between the wood and the bark; and that a transverse section of such trees presents the appearance of a series of nearly concentric irregular rings, the number of which indicates the age of the tree. The relative thickness of these annular markings depends on the more or less flourishing state of the plant during the years in which they were formed. Each ring may, in some trees, be observed to be subdivided into others, thus indicating successive periods of the same year during which its vegetation was advanced or checked. These rings are disturbed in certain parts by irregularities resulting from branches; and the year in which each branch first sprang from the parent stock may therefore be ascertained by proper sections. These prominent effects are obvious to our senses; but every shower that falls, every change of temperature that occurs, and every wind that blows, leaves on the vegetable world the traces of its passage; slight, indeed, and imperceptible perhaps to us, but not the less permanently recorded in the depths of those woody fabrics.

"All these indications of the growth of the living tree are preserved in the fossil trunk, and with them also frequently the history of its partial decay. Let us now examine the use we can make of these details relative to individual trees, when considering forests submerged by seas, imbedded in peat-mosses, or transformed, as in some of the harder strata, into stone. Let us imagine that we possessed sections of the trunks of a considerable number of trees, such as those occurring in the stratum called the *Dirt-bed* in the Island of Portland.* If we were to select a number of trees of about the same size, we should possibly find many of them to have been contemporaries. This fact would be rendered probable, if we observed, as we doubtless should do, on examining the annual rings, that some of them, conspicuous for their size, occurred at the same distances of years in several trees. If, for example, we found on several trees a remarkably large annual ring, followed at the distance of

* See above, vol. i. p. 398.

seven years by a remarkably thin ring, and this again, after two years, succeeded by another large ring, we should reasonably infer from these trees, that, seven years after a season highly favourable to their growth, there had occurred a season unfavourable to them; and that after two more years, another very favourable season had happened; and that all the trees so observed had existed at the same period of time. The nature of the season, whether hot or cold, wet or dry, would be known with some degree of probability, from the class of tree under examination. This kind of evidence, though slight at first, receives additional and great confirmation by the discovery of every new ring which supports it; and, by a considerable concurrence of such observations, the succession of seasons might be ascertained in geological periods, however minute."

24. MICROSCOPIC EXAMINATION OF FOSSIL TREES.*—The discovery of a process by which the structure of fossil vegetables can be examined with as much facility as that of recent plants, has shed an unexpected light on the ancient botany of our planet. On this plate of glass you perceive a thin film of a dark substance, apparently of varnish. It is a slice of the blackest jet; and, if held between the eye and the light, appears of a rich brown colour, and displays a ligneous structure, resembling that of deal or fir: it is, in fact, a thin section of fossil coniferous wood; for jet is nothing more than the wood of some species of fir or pine, that has undergone the process of bituminization, as I shall presently explain. When viewed under a microscope, the small pittings, which I have mentioned as peculiar to the *Coniferæ* (*Lign.* 162, *figs.* 2 and 3), are distinctly visible. The other specimens before us are silicified woods, prepared in the same manner. A few words in explanation of the mode by which sections of such extreme thinness are obtained may not be uninteresting. A slice is first cut from the fossil wood by the usual process of the lapidary; one surface is ground perfectly flat, and polished, and then cemented to a piece of plate-glass by means of Canada-balsam; the slice thus firmly attached to the glass is next ground down to the requisite

* Medals of Creation, vol. i. p. 65.

degree of tenuity, so as to permit its structure to be seen by the aid of the microscope. It is by this ingenious process that the intricate structure of any fossil plant can now be investigated, and the nature of the original determined with as much accuracy as if it were recent.*

A method discovered by Dr. Franz Schulz, of detecting the internal vegetable structure in lignite, coal, anthracite, &c., consists in treating the coal with nitric acid in a platinum-vessel, and then evaporating the acid by a moderate heat, and igniting the residue until no further empyreumatic vapours are given off; the residue is submitted to the action of nitric acid, and the ignition repeated. Thus prepared, the coal is placed in a platinum-crucible with a lid perforated in the centre, and air is blown from a gasometer through the aperture in the lid, while the crucible is kept at a red heat over a spirit-lamp, so that the coal is slowly consumed. The ash thus obtained is not in the state of coke, as would be the case in the ordinary method of incineration, but forms a brown powder full of white splinters. These splinters, on microscopical examination, are found to be the silicious cellular structure of the original vegetable. By this process vegetable tissue has been detected in the *anthracite* or stone-coal of Pennsylvania, by Dr. Baily.†

The experiments and observations on the structure of plants by the Rev. J. B. Reade have brought to light some interesting facts in illustration of this subject. Mr. Reade states that "by the agency of heat the surrounding silicious matter may be liquefied, and the carbon and gaseous products of the wood dispelled, while the essential characters of the fibrous and cellular structure are undisturbed. The unconsumed portions, which alone constitute the true vegetable frame-work, are thus, as it were, mounted in the fluid silica. This property of vegetable fibre of retaining its form, notwithstanding the action of a high temperature, suggested to me the probability of detecting structure in the ashes of coal; and upon examination, I found that the white ashes of 'slaty coal' furnish most beautiful examples of vegetable remains." In a subsequent paper the author adds the following remarks:—"Having ascertained

* See H. Witham's "Observations on Fossil Vegetables," with plates of the internal structure of plants; also Prof. J. Quekett's "Histological Lectures," and "Histol. Catal. Roy. Coll. Surgeons;" Alex. Bryson's paper on Preparing Fossils for Microscopic Investigation, Edinb. New Phil. Journ. N. S. vol. iii. p. 297; and Dr. Carpenter's *Microscope*.

† American Journal of Science, 2nd series, vol. ii. p. 124.

that the silicious organization of recent plants is not destructible, even under the blow-pipe, it appeared to me a natural inference, that the less intense heat of a common fire would not destroy this silicious tissue in the coal-plants; and my opinion has been confirmed, for I have detected in the white ashes of coal all the usual forms of vegetable structure, viz. cellular tissue, smooth and spiral fibre, and annular ducts. A comparison of the ashes of coal with those of recent plants would doubtless afford some further insight into the nature of fossil vegetables. To mention only one instance,—I have ascertained that the lumps of carbonized matter which occur abundantly in the Upper Sandstone near the Spa at Scarborough are, in all probability, portions of the stems of some arundinaceous or gramineous plants. The structure of the epidermis is precisely similar to that of the oat, consisting of parallel columns, set with fine teeth, dovetailing, as it were, into each other, while the underlying tissue consists of cubical cells, a thin horizontal section exhibiting a series of squares. From these facts it is evident, that the true framework and basis of vegetable structure in the plants of coal is not only entirely independent of carbon, but that it has also resisted the bituminous decomposition which has converted all the carbonaceous materials into a highly inflammable substance." *

Another plan for facilitating the microscopical examination of coal is as follows: †—Soak the coal or lignite in a saturated solution of carbonate of soda for from ten to fourteen days, when it will be much softened, and fine slices may be cut from it with a razor or scalpel; place the slices in strong nitric acid, until they become somewhat bleached; use them without delay, and, if desirous of preserving the preparations, mount them in glycerine.

Prof. Morris recommends a ready mode of preparing coal for examination,—boiling the small fragments in nitric acid, washing, and examining them at once.

25. NATURE OF COAL.—In this stage of our inquiry the nature of the process by which vegetables are converted into the mineral substance termed *Coal* requires additional consideration.

Under the microscope a thin slice of true coal exhibits minute, yellowish, semi-transparent particles, with an intermediate deep-brown substance. The amber-coloured material is of a bituminous nature, and so volatile

* Journal of Science, vol. ii. p. 413.

† For the explanation of this method, the Editor is indebted to Prof. Henfrey. See also *Micrograph. Dict.*

as to be readily expelled by heat before the texture of the coal is destroyed. When the slice is taken in one direction, the yellow particles are seen to be elongated; when cut at right angles, minute circular cross-sections of these bituminous bodies are observed, appearing like cells packed closely together. The intermediate brown substance consists of vegetable fibres and earthy matter. The lengthening out of the component yellow particles is evidently due to the compression of layer on layer of the carbonaceous matter; hence the readiness with which coal usually breaks into cubical masses; the line of fracture passing between and parallel with the compressed particles on four sides of the cube, and across them at right angles to their length, on the other two sides of the cube. The same rule is necessarily followed in the cleavage of every substance containing either elongated particles or elongated cavities,—whether it be clay-slate or mica-schist, timber or pie-crust.

The yellow bituminous particles in the coal are the chemical result of the decomposition of the old vegetable matter, consisting of the loose woody and pithy tissue, chiefly of *Sigillariæ*, *Lepidodendra*, and *Calamites*, which formed the great swamp-jungles of the coal-period. Layer after layer of these dead trees accumulated as swampy peat, intermingled here and there with tree-ferns and coniferous trees, brought from higher ground by floods and freshets, and occasionally overlaid by sand- and clay-beds; and the pulpy mass of black carbonaceous mud, similar to what may now be found at the mouths of the tropical rivers and in the swamps of the Mississippi, underwent those gradations of change which converted the woody fibre of the plants into the hydrocarbon of the coal. Hence the endless varieties of cannel-coal and ordinary coal. The former not unfrequently contains the remains of *Anthracosiæ*, *Myalinæ*, and Fishes, and, at Pictou, of Reptiles. Cannel-coal has more earthy and animal matter than common coal contains; and frequently alternations of thin layers of earthy cannel and bright black bituminous coal are observable in common coal.

The Boghead or Torbane Hill coal ("Bitumenite" of Dr. Trail) appears to be a modification of the usual form of cannel-coal; the constituent bituminous particles being larger, less compressed, and more radiated in their inner structure. The "Albertite," found at Hillsborough, New-Brunswick, is still more bituminous, and is amorphous in its composition.

In the dust and the ashes of coals fragments of reticulated and dotted tissue, and of pitted fibres, may be readily found, forming interesting microscopical objects. The scalariform tissue of Sigillaria is not unfrequent in the cannel-coals. Even in the anthracite or stone-coal of North America, which is a hard slaty rock, the vascular tissue may be rendered distinctly visible.

The best specimens of pitted fibre (coniferous wood) are obtained from

the dusty charcoal-like substance often seen on fresh surfaces of coal. This "mother-charcoal" is supposed to be the relics of the drifted conifers, the wood of which appears not to have readily mingled with the swamp-peat.*

Mr. Parkinson, whose work on Organic Remains abounds in interesting observations and experiments on the fossilization of vegetable substances, has argued, that the formation of coal has depended upon a change which all vegetable matter undergoes when exposed to heat and moisture, under circumstances that exclude the air, and prevent the escape of the more volatile principles.† In this condition, a fermentation, which he terms the bituminous, takes place, of which the phenomenon exhibited by *mow-burnt hay* is a familiar example. The production of sugar, and, by continuance of the process, of vinegar, is effected by ve-

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* Besides the works of Lyell already alluded to, and De la Beche's "Geolog. Observer," and other general treatises, especially Prof. Ansted's "Elem. Course of Geology," &c., the student is especially referred, for the consideration of the nature and structure of coal, to the following works: Dr. Redfern "On the Nature of the Torbane Hill and other Varieties of Coal," Quart. Journ. Microsc. Science, vol. iii. p. 106; Prof. Balfour "On the Structure of Coal," Annals Nat. Hist. 2nd ser. vol. xiv. p. 229; Prof. Quekett "On the Intimate Structure of a Peculiar Combustible Mineral from the Coal-measures of Torbane Hill, near Bathgate, Linlithgowshire," Transact. Microsc. Soc. N. S. vol. ii. p. 34; Dr. Hooker "On the Vegetation of the Coal-period," Mem. Geol. Survey, vol. ii. part 2; Prof. Harkness "On Coal," Edinb. N. Ph. Journ. vol. lvii. p. 66, and "On Mineral Charcoal," *ib.* N. S. vol. i. p. 73; Prof. J. W. Dawson "On the Coal-measures of the South Joggins," Quart. Journ. Geol. Soc. vol. x. p. 1; Mr. G. Tate's "Fossil Flora of the Mountain-Limestone Formation of the Eastern Borders;" and his papers on the subject in the Trans. Berwicksh. Nat. Field-club, vol. iii. pp. 134, 195, and 218; and Mr. Newberry "On Cannel-coal," Americ. Journ. Science, 2nd ser. vol. xxiii. p. 212, and Edinb. N. Ph. Journ. N. S. vol. v. p. 364 and vol. vi. p. 368.

Many valuable remarks on the similarity of physical and chemical conditions exhibited by peat-moss, lignite, and coal are to be found in the "Essays on the Natural History and Origin of Peat-moss," by the Rev. R. Rennie, 8vo, Edinburgh, 1810; and also in Leo Lesquereux's Memoir in the Bullet. Soc. Sc. Nat. Neuchâtel, vol. i. p. 471, and Quart. Journ. Geol. Soc. vol. iv. part 2, Miscell. p. 30.

† Organic Remains of a Former World, vol. i. p. 181.

getable fermentation in the open air. In the process of hay-making, the saccharine fermentation is induced, and the grass acquires a peculiar fragrance and sweetness; but in wet seasons, when the hay is prematurely heaped together, the volatile principles cannot escape from the inner mass of vegetable matter, heat is rapidly evolved, a dense vapour exhales, and at length flames break forth, and the stack is consumed. When the process is interrupted, and combustion prevented, the hay is found to have acquired a dark-brown colour, a glazed or oily surface, and a bituminous odour. Were vegetable substances, under the circumstances here described, placed beneath great pressure, so as to confine the gaseous elements, bitumen, lignite, or coal might be produced, according to the various modifications of the process. Vegetable matter is thus traced through every stage of the saccharine, vinous, acetous, and bituminous fermentations; producing alcohol, ether, naphtha, petroleum, bitumen, amber, and even the diamond; and explains that by the process of bituminization stems and branches have been converted into brown-coal, lignite, jet, coal, and anthracite.

According to analyses made at the Museum of Practical Geology * the Newcastle coal has a specific gravity, varying from 1.23 to 1.31, and consists of

Carbon	from	78.01	to	85.58
Hydrogen	—	5.04	—	5.56
Nitrogen	—	0.72	—	1.84
Sulphur	—	0.71	—	1.85
Oxygen	—	2.40	—	10.31
Ash	—	2.14	—	9.12

The percentage of coke left by this coal varies from 35.60 to 72.31.

Iron- and copper-pyrites abound in many of the beds of coal; † and, indeed, these metallic substances are very generally met with in accumulations of carbonized vegetables. The carburetted hydrogen, with the acid and extractive matter, resulting from vegetable decomposition, are adequate to produce copper-pyrites, and even metallic copper, from water holding salts of copper in solution. The pyrites so abundant in the Wealden strata of the Isle of Wight, in the Gault, the Kimmeridge Clay, the Lias, and other formations has originated from this cause.

Prof. W. B. Rogers has some interesting remarks on the origin and accumulation of the proto-carbonate of iron in coal-measures, in *Silliman's*

* The Parliamentary "Reports on the Coals suited to the Steam Navy," by Sir De la Beche and Dr. L. Playfair, 1848—51.

† Some observations on the presence of certain metals in coal will be found in the Report of the Brit. Assoc. 1856, Sect. p. 51.

Journal,* where he shows that, accompanying the coal-beds, were deposits containing much organic matter, and impregnated with sesquioxide of iron, which by the influence of the changing vegetable matter, and the emitted carburetted hydrogen and carbonic acid, became converted into the protocarbonate. (See p. 767, *note*.)

26. LIEBIG ON THE FORMATION OF COAL.—The nature of these changes is thus explained by the eminent chemist, Baron Liebig. Vegetable substances after death undergo two processes of decomposition; namely—

1st. *Fermentation* or *decay*, which is a slow process of combustion (*eremacausis*), in which the combustible parts of a plant unite with the oxygen of the atmosphere; for the decay of woody fibre in contact with air or oxygen converts the latter into an equal volume of carbonic acid; the presence of water and a certain temperature being necessary. Woody fibre in a state of decay forms *humus*.

2dly. *Mouldering* or *putrefaction* of wood subjected to the action of water, and more or less excluded from the air. When pure ligneous fibre, as linen, for example, is placed in contact with water, considerable heat is evolved, and the vegetable matter loses its coherence, and becomes a soft friable mass; in short, it undergoes a true putrefaction.

When all access to air is excluded and consequent oxidation and a removal of a certain quantity of hydrogen, then other changes ensue, and true mineral coal containing combustible oils is the result. In deposits of wood-coal changes are still going on, as is proved by the issue, from clefts in the rocks of the coal-formation, of inflammable gases; such as carburetted hydrogen, nitrogen, and olefiant gas. Thus from the continual removal of oxygen, in the form of carbonic acid, from layers of wood-coal, that substance gradually approaches in its composition to mineral coal. From the latter hydrogen is disengaged in the form of a compound (hydro-carbon); and the removal of all the hydrogen gives rise to *anthracite* or stone-coal.†

The chemical changes of this nature, which are continually taking place in carboniferous deposits, give rise to those evolutions of carbonic acid (*choke-damp*) and carburetted hydrogen, or *fire-damp*, which are frequently so fatal to the miners. And it is a fact worthy of remark, as corroborative of the opinions above advanced, that the bituminous quality

* New. Ser. vol. xxi. p. 339.

† Liebig's Chemistry, translated by Professor Playfair.

of the coal depends on the nature of the bed which immediately covers it. If this be argillaceous shale, the escape of the gaseous matter of the coal is prevented; but, if the roof be arenaceous, the gas is evolved from the coal, and collects in the innumerable fissures and pores of the sandstone, which become filled with carburetted hydrogen, and form as it were a gasometer, ready to explode upon any occasion. Mr. Hutton is of opinion that this gas exists in a highly condensed, and even liquid, state in the pores of the coal; and that the small explosions (termed by the miners eructations) which often take place when the coal is struck with a pick, are due to the sudden expansion of the condensed gas.*

Carburetted hydrogen obtained artificially from coal, peat, oil, and wood,† is well known as "gas," of which such large supplies are now needed for the lighting of our towns. This gas is thrown out naturally from the coal-deposits of many districts; and is sometimes, under those circumstances, used for economical purposes.‡ The fire-temples of Western Asia were, and still are, supplied from this source; at some salt-works in China, they have long used this inflammable gas in evaporating the brine, and lighting the premises; the town of Fredonia, in New York State, is lighted by means of a local supply of the gas; in the Hepburn Colliery, the gas from the coal is used to light the stables; and at Wallsend, a large quantity of gas (11,000 hogsheads a minute) is brought to the surface by iron pipes, and wasted.

27. BITUMEN, PETROLEUM, NAPHTHA.—The changes effected in vegetable matter during its conversion into coal also give rise to various bituminous productions.

Mineral oil is an inflammable fluid which often occurs in carboniferous deposits, sometimes forming powerful springs. *Naphtha* is another liquid of this nature, which is nearly colourless and transparent, burns with a blue flame, emits a strong odour, and leaves no residuum. In driving a level through coal-shale in Derbyshire, springs of naphtha burst forth, and covered the surface of the water in the level; and, having been accident-

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* Sir H. De la Beche, Geological Manual, 3d edit.

† An interesting Report, on the Produce and Value of Wood-gases, is published in the Franklin Institute Journal, No. 380, Aug. 1857, p. 126.

‡ De la Beche's Geol. Observ. p. 409; Tate's Fossil Flora of the Eastern Borders, p. 316. See also Report of Lyell and Faraday, on the Explosion at the Haswell Collieries, 8vo, 1844; with Vertical Section of the Haswell Colliery, Durham: also other Parliamentary Reports on Gases and Explosions in Collieries, by De la Beche and others.

ally set on fire by the approach of a candle, formed a burning spring, which continued some weeks.

Petroleum is of a dark colour, and thicker than common tar; in the carboniferous strata of Coalbrook Dale, and in some parts of Asia, this substance rises from coal-beds in immense quantities. From a careful analysis of petroleum and certain turpentine-oils, it is clear that their principal component parts are identical; and it therefore appears probable that petroleum has originated from the coniferous trees whose remains have contributed so largely to the formation of coal; and that the mineral-oil is nothing more than the turpentine-oil of the pines of former ages,—not only the wood, but also large accumulations of the needle-like leaves of the pines, may have contributed to this process. We thus have the satisfaction of obtaining, after the lapse of thousands of years, information as to the more intimate composition of those ancient forests of the period of the great coal-formation, whose comparison with the present vegetation of our globe is a subject of so much interest. The mineral oil may be ranked with amber, succinite, and other similar bodies which occur in the strata. The springs of petroleum do not seem to depend on combustion, as has been supposed, but to be simply the effect of subterranean heat. According to the information we now possess, it is not necessary that strata should be at a very great depth beneath the surface to acquire a temperature equal to the boiling point of water or of mineral oil. In such a position the oil must have suffered a slow distillation, and have found its way to the surface; or have so impregnated a portion of the earth, as to form springs or wells, as in various parts of Persia and India.*

Bitumen is an inspissated mineral oil, of a dark-brown colour, with a strong odour of tar. In the Odin mine of Derbyshire, elastic bitumen occurs, being of the consistence of thick jelly, and bearing some resemblance to soft India-rubber; as it will remove the traces of a pencil, it has been named "mineral caoutchouc." Some bitumens possess the colour and transparency of amber: the soft varieties may be rendered solid by heat.

From these bituminous substances, we pass by an easy transition to *Amber*, † of which we have already spoken (p. 245); for "black amber,"

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* Dr. Reichenbach. The bituminous products of the border-countries of Turkey and Persia are described by Mr. Loftus, in the Geol. Soc. Journ. vol. xii. p. 269.

† In Liebig's opinion, amber, fossil resin, and mellite are the products of vegetable matter that has suffered *eremacausis* or decay. They are found in wood or brown-coal, and have evidently proceeded from the de-

both in its appearance and composition, closely resembles the solid bitumens.

A mineral called *Mellite*, or honey-stone, from its colour, is found among the bituminous wood of Thuringia, and in its chemical composition, and electrical properties, bears a great analogy to amber; it is usually crystallized in small octahedrons.*

28. THE DIAMOND.—The chemical constituents of the substances above described are chiefly carbon and hydrogen, with a small proportion of oxygen, the essential elements of vegetable matter. But the *Diamond* is pure carbon; at a heat less than the melting point of silver, it burns, and is volatilized, yielding the same elementary products as charcoal.

Sir Isaac Newton remarked, that the refractive power, that is, the property of bending the rays of light, was three times greater in respect of their densities in amber and in the diamond than in other bodies; and he therefore concluded that the diamond was some unctuous substance that had crystallized.

Sir David Brewster observed, that the globules of air (or some fluid of low refractive power) occasionally seen in diamonds have communicated, by expansion, a polarizing structure to the parts in immediate contact with the air-bubble, a phenomenon which also occurs in amber. This is displayed in four sectors of polarized light encircling the globule of air; a similar structure can be produced artificially, either in glass or gelatinous masses, by a compressing force propagated circularly from a point. This cannot have been the result of crystallization, but must have arisen from the expansion exerted by the included air on the amber and the diamond, when they were in so soft a state as to be susceptible of compression from a very small force; hence Sir David Brewster concludes that, like amber, the diamond has originated from the consolida-

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composition of substances which were contained in quite a different form in the living plants. They are all distinguished by their proportionably small quantity of hydrogen. The acid from mellite (mellitic acid) contains precisely the same proportions of carbon and oxygen as that from amber (succinic acid); they differ only in the proportion of their hydrogen. Succinic acid may be obtained by oxidation from wax and from all solid fats.—*Liebig's Chemistry*, vol. i. p. 336.

* Organic Remains of a Former World, vol. i. pl. i. fig. 2.

tion of vegetable matter, which has gradually acquired a crystalline form by the slow action of corpuscular forces.*

Liebig concurs in the opinion that the diamond is of vegetable origin, and offers the following remarks on its probable mode of formation.

"If we suppose decay to proceed in a liquid containing carbon and hydrogen, then a compound with still more carbon must result, in a manner similar to the production of the crystalline colourless *naphthalin* from a gaseous compound of carbon and hydrogen. And, if the compound thus formed were itself to undergo further decay, the final result must be the separation of carbon in a crystalline form. Science can point to no process capable of accounting for the origin and formation of diamonds, except that of decay. Diamonds cannot have been produced by the action of fire; for a high temperature and the presence of oxygen gas would call into play their combustibility. But there is the greatest reason to believe that they have been formed in the humid way; and the process of decay is the only cause to which their formation can with probability be ascribed." †

By voltaic action the diamond has been converted into a substance possessing the appearance, physical character, and electrical properties of *coke*. In this state the diamond loses its insulating power, and becomes lighter: the specific gravity of an ordinary diamond is 3.368; when changed into coke, 2.679.‡

The diamond in a pure state is colourless and transparent; when coloured, it contains foreign matter, as metallic oxides, &c. A blue diamond (the property of Mr. H. T. Hope), weighing 177 carats, is a splendid and unique specimen of this precious gem. There are pink, orange, yellow, and dark-brown diamonds. The largest-known diamond belongs to the Rajah of Mattan; it is of the purest water, and weighs 367 carats, or (at the rate of four grains to a carat) three ounces troy weight: it is egg-shaped. The Mogul Diamond,§ called the Koh-i-noor, or "mountain of light," weighed when first found 793 carats; when exhibited at the Crystal Palace (1851) it weighed 186 carats; it was recut in 1852, and now weighs 102.

The matrix of the diamonds found in Central and Southern India is a wide-spread conglomerate, overlying the sand-stones, limestones, and gneiss-rocks of the country.

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* Geol. Trans. 2nd ser. vol. iii. p. 459. † Liebig's Chemistry, vol. i. p. 336. ‡ Experiments of M. Jacquelin and Prof. Faraday.

§ See Prof. Tennant's interesting observations on this great diamond, and the probable history of its division into three portions, one of which (the Koh-i-noor) is now at Windsor Castle; Transactions of the Society of Arts, 1852, p. 336.

29. ANTHRACITE, PLUMBAGO, &c.—The coal commonly used for domestic purposes in this country is the bituminous, of which there are many varieties, such as cherry-coal, caking-coal, splint-coal, and cannel-coal.* The *Anthracite*,† culm, or stone-coal, is coal usually deprived of its bitumen by the causes already explained; anthracitic bands, however, occasionally are intercalated with seams of bituminous coal. When coal is near to trap or basalt, it is often in the state of anthracite; while the layers in immediate contact with the volcanic rocks are charred, and in some instances coked; or the mass is converted into *plumbago*, or *graphite*, the substance used for drawing-pencils. By a series of interesting experiments, Dr. Macculloch‡ demonstrated the transitional changes from bitumen to plumbago. Hydrogen predominates in the fluid bitumen; bitumen and carbon in coal; in anthracite, bitumen is altogether wanting; and in plumbago, the hydrogen has also disappeared, and carbon only or chiefly remains.

In North America, from the prevalence of anthracite in the carboniferous deposits, this substance is in nearly universal use; but in England it is seldom employed except in Arnott-stoves and the furnaces of our manufactories.§ This kind of coal is, however, largely developed in many districts; and the anthracite of South Wales extends from the Vale of Neath, on the east, to St. Bride's Bay on the west. Some of this coal is in the state of charcoal, and requires a degree of heat of 531° Fahrenheit, for its ignition; but, when ignited, it burns with a bright flame, and is the most durable of fuel.

30. PETRIFACTION OF VEGETABLES. — As in the sand-

* See Parliamentary Reports on the coals suited for the steam-navy.

† From the Greek *ανθραξ*, signifying coal or charcoal.

‡ Transact. Geol. Soc. vol. ii. p. 1.

§ The anthracite of the Alleghanies is of very slow combustion; but this is overcome by freely supplying oxygen by means of a blower, even in the fire-places of private dwellings: and the drying effect on the air of the apartments is counteracted by the evaporation of water.

stones and other strata the stems of trees and plants are often found not in the state of coal, but converted into stone —in some instances calcareous, in others silicious, I shall in this place offer a few remarks in illustration of the process by which such a change has been effected.

In true petrifactions a transmutation of the parts of an organized body into mineral matter takes place. Patrin, Brongniart, and other philosophers suppose that petrifaction has frequently been effected suddenly, by the combination of gaseous fluids with the constituent principles of organic structure. It appears, indeed, certain, that the conversion of animal and vegetable substances into silex must, in many instances, have been almost instantaneous; for the most delicate parts, those which would undergo decomposition with the greatest rapidity, are preserved. The occurrence in the Oolite, at Tisbury, of Trigonias, having their delicate branchiæ and other portions of the body preserved in their natural position by silicification (p. 527), illustrates these remarks. So also does the preservation of a zoophyte in agate, as described and figured by Mr. Bowerbank.* The fact of the silicification of trees in loose sand, and of the soft bodies of molluscs in their shells, as in the fossil oysters found in the chalk at Brighton,† while neither the sand nor the shells are impregnated with silex, cannot be explained by the infiltration of a silicious fluid into cavities left by the decomposition and removal of the animal substance.‡ Von Buch has shown that the silicifying process never immediately attacks the calcareous shell, but developes itself only upon the organic matter, and that, where this substance is not present, no silicification takes place. A combination of gaseous fluids with the constituent principles of the animal or vegetable substances, changing the latter into stone without modifying the arrangement of the molecules so as to alter

* Journ. Geol. Soc. vol. v. p. 319. See also *ibid.* p. lxxviii., Anniversary Address by Sir H. De la Beche, for some remarks on this interesting fossil, and on silicification generally.

† Medals of Creation, p. 374.

‡ It still remains for some patient investigator to elucidate the as yet mysterious relations of carbon and silicon, and to recover the broken clue to this research left by the untimely death of Dr. Samuel Brown, of Edinburgh. His early experiments on the transmutation of these two substances appear to have been followed in later years by more certain results, which, however, this lamented chemist had not published at the time of his death. See the deeply interesting article on Dr. S. Brown and Prof. E. Forbes, in the North British Review, February, 1857.

the external form, seems the only mode by which such transmutations can have been effected. The production of congelation, by a simple abstraction of caloric, is akin to this change; but petrifaction is induced by the introduction of another principle. As to density, the most subtle gas may acquire the greatest solidity; as, for example, in the union of oxygen with metallic substances.

The following remarks, selected from Mr. C. Stokes's observations * on fossil wood and plants, throw light on this subject. The specimen which gave rise to these remarks was a piece of beech-wood, partly petrified by carbonate of lime, from a Roman aqueduct in Germany. In this wood were several insulated portions converted into carbonate of lime, while the remainder was unchanged.

Sometimes the most minute structure is preserved, as in the vessels of palms and coniferæ, which are as distinct in the fossil as in the recent trees. From this state of perfection, we have every degree of change, to the last stage of decay: the condition of the wood, therefore, had no influence on the process. The hardest wood, and the most tender and succulent, as, for instance, the young leaves of the palm, are alike silicified. In some instances, the cellular tissue has been petrified, and the vessels have disappeared; here silicification must have taken place soon after the wood was exposed to the action of moisture, because the cellular structure would soon decay; the process was then suspended, and the vessels decomposed. In other examples, the vessels alone remain; a proof that petrifaction did not commence until the cellular tissue was destroyed. The specimens where both cells and vessels are silicified show that the process began at an early period, and continued until the whole vegetable structure was transmuted into stone.

In a morass near Ferry-bridge, in Yorkshire, a similar partial petrifaction of the stems and branches of trees has taken place.†

The late Dr. Turner, in some admirable comments on the subject of petrifaction, remarked, that, whenever the decomposition of an organic body has begun, the elements into which it is resolved are in a condition peculiarly favourable to their entering into new combinations; and that, if water, charged with mineral matter, come in contact with bodies in this state, a mutual action takes place, new combinations result, and solid

* Transactions of the Geological Society, 2nd ser. vol. v. p. 212.

† Described by Mr. Stokes, *op. cit.* p. 211.

particles are precipitated, so as to occupy the place left vacant by the decomposed organic substance.

31. Artificial Vegetable Petrifactions.—Prof. Göppert has published the result of an interesting investigation of the condition of fossil plants, and the process of petrifaction. Layers of ironstone-nodules, as we have previously stated, are common in the carboniferous strata. They appear to have once constituted continuous layers, the nodules having been produced by segregation, *i. e.* the substance of which they are composed has separated from the constituent parts of the rock after deposition.* The first segregation often appears to have been caused by the presence of some extraneous matter, sometimes a trilobite or a shell, and very commonly the leaf of a fern.† Parkinson had remarked, that the leaves in these nodules might sometimes be separated in the form of a carbonaceous film; and Göppert, having found similar examples, was induced to undertake a set of experiments. He placed fern-leaves in clay, dried them in the shade, exposed them to a red heat, and obtained striking resemblances to the fossil plants. According to the degree of heat, the plant was found to be either brown, shining black, or entirely lost, the impression only remaining; but in the latter case the surrounding clay was stained black, thus indicating that the colour of the coal-shales is from the carbon derived from the plants they include. Plants soaked in a solution of sulphate of iron were dried and heated until every trace of organic matter had disappeared, and the oxide was found to present the form of the plant. In a slice of pine-tree the pitted fibres peculiar to this family of vegetables were perceptible. These results by heat are probably produced naturally, by the action of moisture under great pressure, and the influence of a high temperature.‡

* Sir H. De la Beche, Researches in Theoretical Geology, p. 96.

† Medals of Creation, p. 69 and p. 522.

‡ Quart. Journ. Geol. Soc. vol. vi. part 2, Miscell. p. 33.

32. SILICIFICATION OR PETRIFACTION OF VEGETABLES BY SILEX.—The various forms in which silex is found have been probably dependent on its state of solution; in the case of quartz-crystals it was entirely dissolved; in agate and chalcedony it is supposed to have been in a gelatinous state, assuming a spheroidal or orbicular disposition, according to the motion given to its molecules. Its condition appears also to have been modified by the influence of organic matter. In some polished slices of flints from Bognor, the transition from flint to agate, chalcedony, and crystallized quartz is beautifully exhibited. The curious fact, that the echinites in the chalk are almost invariably filled with flint,* while the shelly covering is converted into calcareous spar, is, perhaps, attributable to the animal matter having undergone silicification;† for the most organized parts are those which appear to have been most susceptible of silicious petrifaction. Allusion has been already made to the conversion of an oyster into flint, while the shell is, as usual, carbonate of lime. The shells of mollusca, the plated coverings of echinoderms, and the guards of the belemnites are less commonly silicified, possibly from the large proportion of calcareous earth which enters into their composition; they are more frequently changed into calc-spar, probably from water charged with carbonic-acid gas having insensibly effected the crystallization of their molecules.‡

Some specimens of silicified wood, collected from the interior of Australia, by the late Sir T. Mitchell, and now in the British Museum, are entirely permeated by silex; but on the external surface of these stems, there are some circu-

* In one instance, the shell of an echinite from the chalk is transmuted into crystallized carbonate of lime, while the lower portion of the cavity is occupied by flint, on which is a layer of crystals of calcareous spar.

† Mr. Bowerbank thinks that the cavities of the echinoderms were filled, after death, by sponge, which latter took on the silicification.

‡ See an interesting Essay on this subject, by M. Alexandre Brongniart, "*Essai sur les Orbicules Silicieux, &c.*" Paris, 1831.

lar spots of chalcedony, that appear to have originated from the exudation of the liquid silex from the interior, in viscid globules distended with air, which burst, collapsed, and became solidified in their present form.

One of the most eminent naturalists and mineralogists of the United States, Mr. J. D. Dana,* has suggested that the reason why silica is so common a material in the constitution of fossil wood and shells, as well as in pseudomorphic crystals, consists in the ready solution of silex in water at a high temperature (a fact affirmed by Bergman),† under great pressure, whenever an alkali is present (as is seen at the present time in many volcanic regions), and its ready deposition again when the water cools. A mere heated aqueous solution of silica, under a high pressure, is sufficient to explain the phenomenon of the silicification of organic structure. Mr. Dana states, that a crystal of calc-spar in such a fluid being exposed to solution from the action of the heated water alone, the silica, depositing itself gradually on a reduction of temperature, takes the place of the lime, atom by atom, as soon as set free. Every silicified fossil is an example of this pseudomorphism; but there seems to be no union of the silica with the lime, for silicate of lime is of rare occurrence. (See also vol. i. p. 99, &c.)

That silicification is induced under circumstances connected with a high temperature, we have a remarkable instance in the petrified wood observed in Kerguelen Island, by Captain Sir James Ross. Seams of coal, varying in thickness from a few inches to four feet, are imbedded in trap-rock; and numerous fossil trees were found lying under a bed of shale, which was covered by a mass of basalt several hundred feet thick. Some portions of the wood were so

* Americ. Journ. Science and Arts, vol. xlviii. p. 84.

† Bergman first determined the solubility of silex in simple water, aided by heat, and demonstrated its existence in the Geysers, and other boiling springs of Iceland. See also Parkinson, Org. Rem. vol. i. p. 324.

little altered that it was necessary to take them in the hand to be convinced of their fossil state; and the wood was found passing from that condition into charcoal which would burn freely; while other portions were so completely silicified as to scratch glass.* In fact, the permeation of vegetable tissues by aqueous solutions of silex at a high temperature appears to be one of the necessary conditions under which silicification takes place.

33. FOSSIL PLANTS OF THE COAL.†—I proceed to the examination of the flora of the Carboniferous era. The layers of pure coal, as we have already stated, are wholly composed of carbonized vegetables; and, when we consider that these beds are from ten to thirty feet and even nearly fifty in thickness,‡ it would seem difficult to account for such an immense accumulation of wood, and plants, and foliage as would be required to produce so enormous an amount of carbon, without any intermixture of earthy detritus, had we not such illustrative examples of analogous modern carbonaceous deposits, as those brought forward by Sir C. Lyell, and previously alluded to. The shales above the coal are highly charged with carbonaceous matter, and contain a profusion of leaves and stems. The vegetable remains are always in a carbonized state; but the leaves sometimes possess such a degree of tenacity and elasticity as to be separable from the stone. The leaves and seed-vessels which occur in the iron-stone-nodules have, in many instances, undergone a metallic impregnation, as is often the case in specimens from Coalbrook Dale. Brilliant sulphide

* Voyage of Discovery in the Southern and Antarctic Regions, in 1839-43.

† Plates I. to XXX. of the Pictorial Atlas of Organic Remains (from Artis and Parkinson) are devoted to Fossil Plants.

‡ Besides the instances of thick coal-seams mentioned at p. 683, we may add that at Wilkesbarre in Pennsylvania an anthracite, 30 feet thick, is worked; and near Cracow in Poland there is a coal-bed between 40 and 50 feet thick.

of iron (iron-pyrites), in some examples, permeates the entire vegetable tissue; in others, the stems and leaflets are replaced by white hydrated silicate of alumina (pholerite);* and in many, by crystals of galena, or sulphide of lead, and of blende, or sulphide of zinc. In the sandstones, the stems have generally a carbonaceous crust, and their internal structure is sometimes found in a calcareous, and occasionally in a silicified, state.

The Coal-plants which have been accurately determined† amount to some hundreds of species, of which two-thirds are either members of the family of Ferns, or belong to extinct orders of plants that united the characters of the existing cryptogamic and gymnospermous classes.‡ The remainder consist of Coniferæ, some Cycadaceæ, and a few flowering monocotyledonous or dicotyledonous plants.§ But

* See Pict. Atlas Org. Rem. pl. 5, figs. 10, 11. Geol. Jour. vol. xiii. p. 16.

† In his "Steinkohlen-Formation Sachsen's," 1856, Dr. Geinitz has published the latest results of his long and diligent examination of great numbers of the plant-remains of the coal; and has shown that, from the evidence afforded by the carefully collected leaves, stems, roots, and fragments, many of the hitherto accepted "species" must be merged together; different parts of the same plant having been severally regarded as fragments of distinct plants, or variously conditioned individuals of one species having been catalogued as distinct species. Would that there were more British geologists able and willing to rival Gœppert and Geinitz in their laborious, conscientious, and successful elucidation of the fragmentary and often obscure relics of the Carboniferous Flora!

‡ Thus the Lycopodiaceæ and Coniferæ meet, as far as analogical resemblances are concerned, in the *Lepidodendron;* and the Ferns and the Cycads in the *Sigillaria;* whilst the Equisetaceæ appear with added characters in the *Annulariæ* and the *Calamites*.

§ Adolphe Brongniart's Memoirs on Fossil Vegetables—especially his "Prodome," and "Histoire des Végétaux Fossiles," 1828, and "Tableau des Genres de Végétaux Fossiles," 1849—should be consulted for philosophical views of the condition of the terrestrial vegetation at the Carboniferous period. With reference to this subject he observes, in his interesting memoir on the genus *Nœggerathia* (Annales des Sc. Nat. 1846), that the Carboniferous Flora appears to have been limited to two of the

numerous species are undescribed, and new forms are continually being discovered.

The British species exceed 200;* I will presently place before you a few of the predominant forms, which will serve to convey a general idea of the nature of the Carboniferous Flora; for the greater number of the plants that are found in the British coal-mines also occur in Europe and North America,—even in the Arctic regions.

The following tabular outline of the characteristic families and general classification of existing vegetables† will be useful to the student, when referring the fossil plants to their modern representatives.

- Acotyledonous or Cryptogamic.
  - Thalogens; or Cellular Cryptogams. Diatomaceæ, Desmidiaceæ, Confervæ, Seaweeds, Charæ, Mould, Mushrooms, Lichens, &c.
  - Acrogens; or Vascular Cryptogams. Liverworts, Horsetails, Mosses, Club-mosses, Pepperworts, Ferns, &c.
- Phanerogamic.
  - Monocotyledonous.
    - Endogens. Grasses, Palms, Orchids, Rushes, Lilies, &c.
  - Dicotyledonous.
    - Gymnogens; or Gymnospermous Dicotyledons. Cycadaceæ and Coniferæ.
    - Exogens; or Angiospermous Dicotyledons. Most of the European flowering herbs and trees (except the Conifers,—firs, yews, &c.).

That we may have a general view of the Carboniferous Flora, the following synoptical résumé of the specific determinations of the coal-plants, by Gœppert and Geinitz, is given. These results are founded on a close study of the plants of the Upper and Lower Coal of Saxony, compared with those of the coal-measures of Silesia and other parts of the Continent, and of Britain; and necessarily afford valuable statistics of the vegetation of the Coal-period, although other palæontologists may be

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grand divisions of the vegetable kingdom, namely, "les Cryptogames acrogènes ou vasculaires, et les Phanérogames dicotyledones gymnospermes." See also Lyell's "Manual of Geology," 5th edit. p. 373.

* See Morris's "Catalogue of British Fossils," 1854; and Phillips's "Manual of Geology," p. 226.

† See "Manual of Natural History" (Van Voorst), for a detailed classification. For structure, see Carpenter's *Microscope*, chapters 6, 7, and 8.

inclined to disagree in many points with the results at which these eminent German geologists have arrived.

A. Acotyledones.

1. Fungi.
   Depazites, Excipulites, Gyromyces (one species of each).
2. Equisetaceæ.
   Equisetites (2 species), Calamites (6 spec.).
3. Asterophyllitæ.
   Asterophyllites (6 spec.), Annularia (3 spec.), Sphenophyllum (6 spec.).
4. Filices.
   a. Sphenopterideæ.
   Sphenopteris (18 spec.).
   Hymenophyllites (7).
   Schizopteris (4).
   b. Neuropterideæ.
   Odontopteris (3 spec.).
   Neuropteris (5).
   Cyclopteris (3).
   Dictyopteris (2).
   c. Pecopterideæ.
   Cyatheites (10).
   Alethopteris (10).
   Oligocarpia (1).
   d. Protopterideæ.
   Caulopteris (3).
   Palæopteris (1).
   Psaronius (1).
   Megaphytum (1).
5. Lycopodiaceæ.
   Lycopodites (5).
   Selaginites (1).
   Lepidodendron (2).
   Sagenaria (5).
   Lepidophyllum (1).
   Aspidaria (4).
   Halonia (3).
   Knorria (3).
   Cardiocarpon (4).

B. Dicotyledones.

6. Nœggerathieæ.
   Cordaites (2).
   Nœggerathia (4).
   Rhabdocarpos (4).
7. Cycadeæ.
   Trigonocarpon* (3).
8. (?)
   Carpolithes (3).
9. Coniferæ.
   Pinites.
10. Sigillariæ.†
    Sigillaria (13).
11. Stigmariæ.
    Stigmaria.‡

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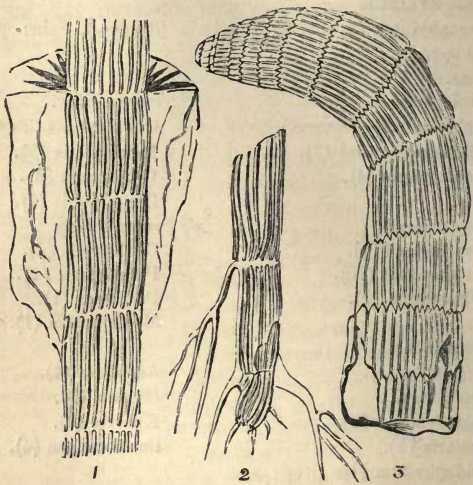
* Dr. Hooker refers the fruits thus named to *Coniferæ*.

† Closely related to the *Lepidodendron*, according to Dr. Hooker.

‡ Gœppert and Geinitz regard the *Stigmaria ficoides* as an independent plant; and consider others of the so-called Stigmariæ to be the roots of *Sagenariæ*.

34. EQUISETACEOUS PLANTS. — The stems of several gigantic plants (*Calamites*) allied to the *Equisetum fluviatile*, or Horse-tail of our marsh-lands, are very abundant in the coal-measures. While the recent species seldom exceed two feet in height, and half an inch or an inch in diameter, the fossil stems often attain twenty or thirty feet in height, and



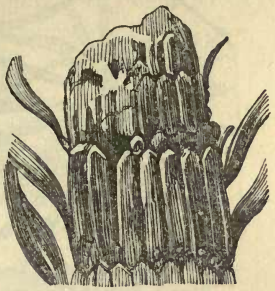
LIGN. 163.—CALAMITES FROM THE COAL-FORMATION.

Fig. 1. Portion of a stem, with half of a whorl of leaves or bracts. (Half nat. size.)
— 2. Portion of stem with roots. (Half nat. size.)
— 3. Terminal portion of a stem [drawn upside down]. (One-fifth nat. size.)

fourteen inches in diameter. The *Equisetites columnaris* is a common species of this kind of plant in the Lower Oolite of Yorkshire; and both the Calamite and the Equisetite are occasionally found in an erect position in the strata.*

* See Dawson's remarks on Upright Calamites at Pictou, Journ. Geol. Soc. vol. vii. p. 194, and vol. x. pp. 21 and 35; also T. T. Wilkinson's notice of Upright Calamites, accompanying a considerable number of fossil upright and rooted trees at Burnley; Lanc. and Chesh. Hist. Soc. Trans. vol. ix. p. 101.

Calamites. The plants of this extinct genus much resemble the Horsetail, being furrowed longitudinally, and intercepted with joints or nodes. But in several points they differ, both in external characters and in internal structure.* Calamites are so abundant in the coal as to prove that they constituted an important feature in the flora of the countries of the carboniferous age; and they have also been found in strata both above and below the coal, and range from the Devonian to the Permian, and probably to the Jurassic period. A small fragment of the terminal portion of a stem, with rootlets, is represented in *Lign.* 164, and illustrates the characteristic tubercles accompanying each articulation, and marking probably the place of attachment of bracts in the upper, and rootlets in the lower part of the stem.

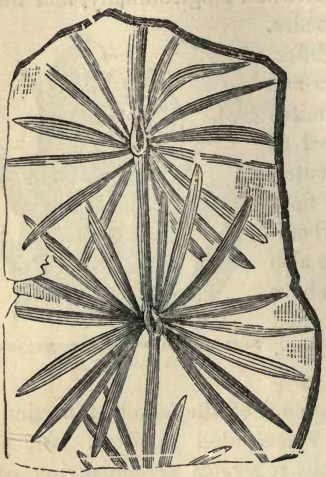


LIGN. 164.—CALAMITES CANNÆFORMIS; from Coalbrook Dale.

The stem of the *Calamodendron* (Brongniart) consisted of, 1st, an outer thin cylinder of bark and wood, of a high organization, externally marked with longitudinal furrows and riblets; and 2ndly, an inner pith or cylindrical axis of soft tissue, also ribbed lengthwise, but distinctly marked by transverse joint-like depressions, forming such articulations as those of the common Calamite. Along these cross-lines the interrupted riblets of the pith met and dovetailed one with another; and from the upper end of each riblet, as

* See J. S. Dawes on the Calamite, Geol. Soc. Journ. vol. vii. p. 196; where many references to other writers on these peculiar fossil plants will be met with. See also Brongniart's and Williamson's Elucidation of the Structure of Calamites and Calamodendron, in Lyell's "Manual," 5th edit. p. 368.

in Calamites, a bundle of vessels went off into the outer wood.



LIGN. 165.—ASTEROPHYLLITES EQUISETIFORMIS; from Coalbrook Dale.

*Asterophyllites.** Plants with verticillate leaves are common in the coal-shales; they have been named *Asterophyllites*, *Annularia*,† *Sphenophyllum*,‡ &c. Several of these slender whorl-leafed plant-remains are equisetaceous in their aspect; and some were the branches and foliage of the Calamodendron. Others were probably small plants abounding in the shades of the swampy forests; and others long floating water-plants. Two of the usual forms are here represented (*Ligns.* 165 and 167, *fig.* 1).

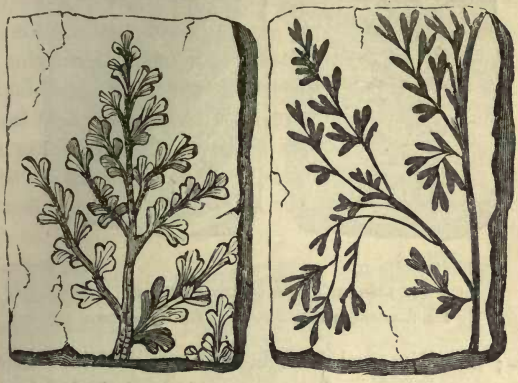
35. FOSSIL FERNS.—The *Brake* or Fern of our commons and waste lands is a familiar example of a remarkable and numerous family of plants, distinguished by the peculiar distribution of their seed-vessels. The arborescent ferns of the tropics rise into trees from thirty to forty feet in height, their stems being marked with scars from the decay of the leaf-stalks, and their summits covered with an elegant canopy of foliage; § their general appearance is shown in

* *Star-leaf.* Medals of Creation, p. 146. † Petrif. p. 27, *Lign.* 2.

‡ *Wedge-leaf.* Medals, p. 148, *Lign.* 43.

§ A lucid and pleasing description of the external features of a tree-fern may be found among the many graphic pictures of plants and animals, of which Mr. Gosse's suggestive work, entitled "Omphalos," is mainly composed (pp. 129–132).

Lign. 180, *fig.* 5, p. 754. The leaves of the herbaceous species are very elegant, and present great variety in their forms, and in the mode in which the veins of the leaf are



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LIGN. 166.—FROM THE CARBONIFEROUS STRATA AT BURDIE-HOUSE, SCOTLAND.

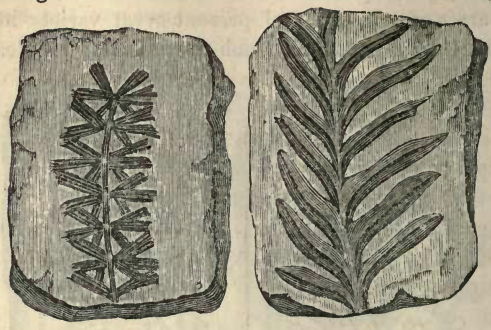
Fig. 1. Sphenopteris linearis. Fig. 2. Sphenopteris affinis.

disposed; from the character of the latter, M. Adolphe Brongniart has established the generic distinctions of the fossil plants of this family. The beautiful state in which these remains occur in the coal-shale is shown in the specimens before us (*Ligns.* 166, 167, *fig.* 2, and 169, *fig.* 3). The young and still uncoiled (or circinate) leaves, and the fructification on the back of the adult leaves, are sometimes preserved.

The stems of ferns, with their elliptical cicatrices, or leaf-scars, bear some resemblance to those of the palms, but are readily distinguished on account of the longest diameter of the scars being vertical, while in the palms it is transverse: sections of the stems of these two tribes have also distinctive characters.* Fossil fern-stems are known as *Caulopteris* and *Psaronites*.†

* Végét. Fossiles, tom. i. pl. 37. † Stenzel; Ueber Farn-wurzeln, 1857

The large tree-ferns are confined almost exclusively to the



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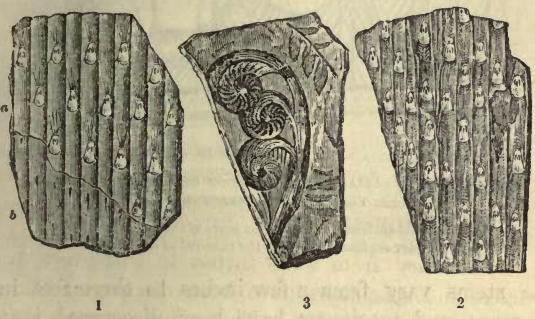
LIGN. 167.—FROM COALBROOK DALE.
Fig. 1. Asterophyllites. Fig. 2. Pecopteris.

tropics; humidity and heat being the conditions most favourable to their development. In the carboniferous rocks there are about 100 species of ferns, nearly all of which belong to the tribe of *Polypodiaceæ;* the common *Polypody*, so frequent on old walls, will convey an idea of the characters of their foliage. The fossil species present great variety and elegance in the form and disposition of the fronds and pinnules. The *Pecopteris* (*Lign.* 167, *fig.* 2, and 168, a genus containing upwards of forty British species, is of frequent occurrence in the coal-shales, and abounds also in the Lower Oolite of Yorkshire.*

LIGN. 168.—PECOPTERIS ADANTOIDES; from Coalbrook Dale.

* See Medals of Creation, pp. 109—124, for figures and descriptions of fossil ferns. Also Bronn's *Lethæa Geogn.*, &c.

36. SIGILLARIA.—Among the most common and striking objects that arrest the attention of a person who visits a coal-mine for the first time, and examines the fossil remains profusely scattered around him, are long flat narrow slabs of a coaly substance, having the surface fluted longitudinally, and uniformly ornamented with rows of deeply imprinted symmetrical figures, disposed with great regularity (*Lign.* 169). These relics are the flattened stems, with or without the bark or rind, of trees of large size: the imprinted markings on the surface being the scars left by the separation of the



LIGN. 169.—SIGILLARIÆ AND FERN, FROM THE COAL-MEASURES.

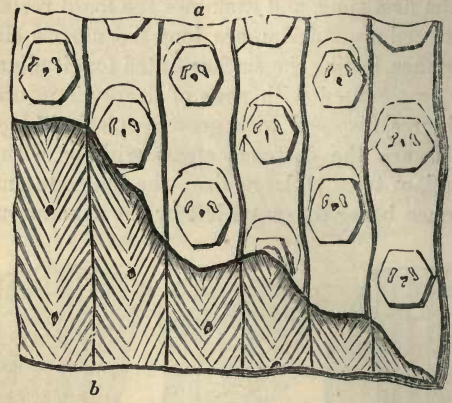
(One-fourth the natural size.)

Fig. 1. Sigillaria Voltzii, from the anthracite of Baden; *a*, the external surface; *b*, the inner surface, a portion of the outer bark being removed.
— 2. Sigillaria Sillimani: from the coal-mines of Pennsylvania.
— 3. Pecopteris Miltoni; a specimen showing the young frond coiled up like a crosier.

petioles or leaf-stalks.* The name *Sigillaria* has been given to these extinct trees, from the impressions appearing as if made by a seal or die. These stems are generally found broken to pieces, and, when lying in a horizontal posi-

* The markings left on a cabbage-stalk by the removal of the leaves are of a similar nature. Figures of Sigillariæ are given in Plates XIX. and XX. of the Pictor. Atlas Org. Rem.

tion in the strata, are quite flat from the pressure of the superincumbent deposits.



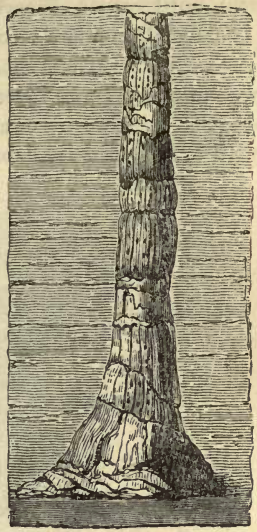
LIGN. 170.—SIGILLARIA SAULII, A PORTION OF A FLATTENED STEM, FROM THE COAL-MEASURES.

a. External surface marked by the scars of the petioles.
b. The inner surface exposed by the removal of the bark.

The stems vary from a few inches to three feet in circumference, and specimens have been discovered that indicate a length of sixty feet. They often escape compression, and stand perpendicularly, intersecting the horizontal strata, and having roots proceeding from the base. They are generally surrounded by an envelope, an inch in thickness, of fine, crystalline, bituminous coal. The longitudinal plaitings, which are the characteristic marks of the Sigillariæ, are commonly indistinct at the base. A specimen figured in the beautiful and highly interesting work of Lindley and Hutton * was ten feet high, and two feet in diameter at the base (*Lign.* 171). Its roots were in shale, immediately above the main bed of coal, and the trunk extended through several strata of shale and sandstone.

* "The Fossil Flora of Great Britain."

The *Sigillaria* was a tall tree, with a bare trunk, regularly pitted by the leaf-scars. It branched at the summit, and appears to have borne long narrow leaves. Its fruit is not known. In its internal structure, which has been examined by Brongniart, King, Hooker, Bowman, Dawson, and others, the *Sigillaria* shows much analogy to that of the *Cycadeæ*, but exhibits also the scalariform tissue of the *Acrogens*; and is regarded as of higher organization than the Lepidodendron, and belonging to a peculiar family of the great division of Gymnospermous Dicotyledons.* It was a plant consisting of soft areolar tissue, with a hard woody central cylindrical axis, and a hard bark. There are many species known of this extinct genus. The *Sigillariæ* abounded in the swampy jungles of the Coal-period, and have evidently supplied the chief mass of the now carbonized material of most coal-seams, whilst their roots (*Stigmariæ*) still permeate the *underclays* in every direction.



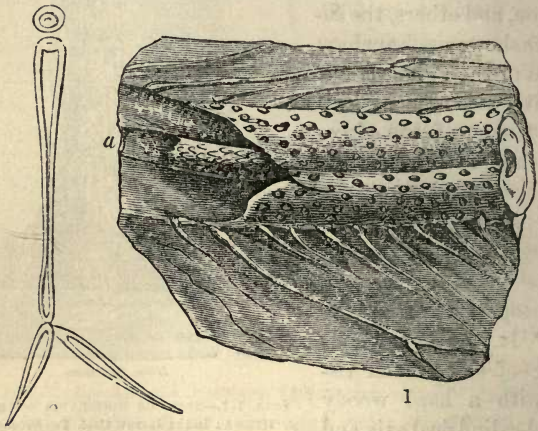
LIGN. 171.—STEM OF SIGILLARIA PACHYDERMA; in the Jarrow Coal. *Ten feet high.*

37. STIGMARIA.†—The fossil vegetables known under this name, which are so abundant in the underclay of the

* See Dr. Hooker's Remarks on *Sigillaria*, Mem. Geol. Survey, vol. ii. part 2, p. 421; and King on *Sigillaria*, Edinb. N. Phil. Journ., 1844.

† Dr. Hooker's Memoir on *Stigmaria*, Mem. Geol. Surv. vol. ii. part 2, p. 431; King, *loc. cit.*; Medals, p. 132, &c.

coal-beds,* long excited the curiosity of collectors, and set at defiance all attempts to determine their botanical characters, until recent discoveries proved the correctness of M. Adolphe Brongniart's conjecture, that they were the roots of *Sigillariæ*. These bodies are of a sub-cylindrical form, reaching sometimes several feet in length, and are often ten or twelve inches in circumference. The surface is covered with oval or circular depressions with a small tubercle in the



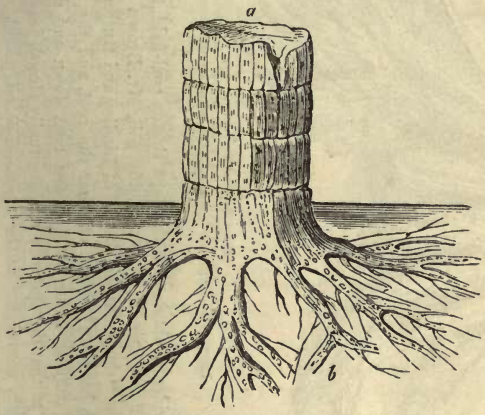
LIGN. 172.—STIGMARIA FICOIDES.

Fig. 1. Portion of a root (⅛ nat. size). The internal axis is seen at *a*.
— 2. One of the rootlets, with a corresponding tubercle, to show the mode of articulation.

middle, disposed in quincunx order. When broken across, a small cylindrical axis or core is found to extend longitudinally throughout the stem (*Lign.* 172). When observed in the underclay, long tapering fibres or rootlets are found attached to the tubercles of the pits with which the surface is covered; and these are sometimes several feet in length.

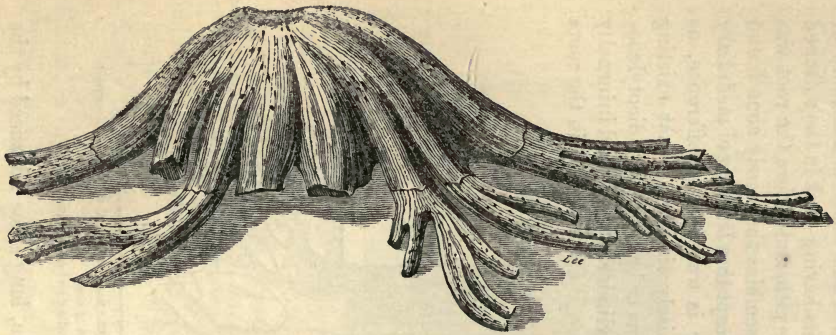
* Prof. Gœppert has remarked that *Stigmaria ficoides* may be regarded as one of the most prevalent of the coal-plants. "Ein-und-dreissig. Jahresbericht. Schles. Ges." p. 81.

The internal structure of the *Stigmariæ* presents a ligneous axis, or cylindrical woody bundle of vessels, originally traversing the centre of the pithy root, but in the fossils generally lying nearer to one side than the other of the more or less compressed root, owing to its having sunk in the softened tissue during the rotting of the pith, and before the root was fossilized. This woody axis resembles the woody zone found in sections of the *Sigillariæ*, except that the ring of medullary tissue possessed by the latter is wanting; a difference, as Ad. Brongniart remarks, precisely similar to that existing between the roots and the stems or branches of a dicotyledonous tree, in which the woody cylinder is associated internally with bundles of medullary tissue, that are absent in the roots



LIGN. 173.—STEM AND ROOTS OF A SIGILLARIA; in a Coal-mine near Liverpool
a, The trunk traversing a bed of coal.
b, The roots (*Stigmariæ*) spreading out in the underclay.

of the same tree. This opinion, long since advanced by the eminent French savant, has been confirmed by Mr. Binney's discovery, in the coal-strata at St. Helen's near Liverpool, of an upright stem of a *Sigillaria*, nine feet high, with ten



(*From the Geol. Soc. Journ* vol v. p. 358.)

LIGN. 174.—STOOL OF A SIGILLARIA BROKEN OFF CLOSE TO THE ROOTS.

Having shown, by evidence obtained in the Cape Breton coal-field, that the Sigillaria was provided with roots peculiarly adapted for flourishing on a soft muddy soil, Mr. Brown refers to the fossil roots figured above, as perfectly resembling the "dome-shaped fossil" of Lindley and Hutton, but as being really the stool of a Sigillaria, the stem of which has been broken off near the root, and the hollow woody cylinder of which had, after the decay of the loose cellular tissue within, been bent down and doubled over by the pressure of the accumulating mud outside, so that the aperture was effectually closed, leaving only a few irregular cicatrices, of three or four inches in length, converging at the apex.—*Loc. cit.* p. 360. See also Mr. Dawson's remarks, to a like effect, *ibid.* vol. x. p. 31.

roots, several feet long, attached, and extending in the underclay in their natural position (as shown in *Lign.* 173); these roots being undoubted *Stigmariæ*.*

In the floor of the Victoria Mine, at Dunkinfield near Manchester, at the depth of 1100 feet from the surface, Mr. Binney discovered a magnificent specimen of Sigillaria, which exhibited on its stem the respective characters of three supposed species (*S. pachyderma, reniformis,* and *organum*), and had stigmaria-roots, which were traced twenty feet.†

In the Sidney coal-field, at Cape Breton, several upright stems of Sigillariæ, having roots that are undoubted Stigmariæ, have been discovered; and in the Pictou coal, in Nova Scotia, the same fact has been noticed, and communicated to the Geological Society of London. (See also p. 689.)

The Rev. Henry Steinhauer was among the first to regard the Stigmariæ as *roots* of trees, in an interesting and well-illustrated memoir, entitled "Fossil Reliquia of Unknown Vegetables in the Coal-strata" (Transact. Americ. Phil. Soc. New Series, vol. i. p. 273, 1818). Lindley and Hutton quoted Steinhauer's observations, and described the Stigmariæ as radiating, massive, floating aquatic plants.‡

Prof. Gœppert has evidence to show that some of the Stigmariæ were great, branching, and even anastomosing roots, or rhizodes, of water-plants; and resembled the spread-

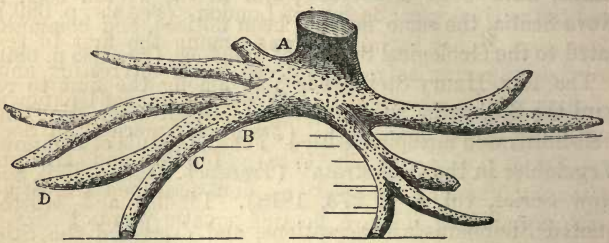
* Phil. Mag. 3rd ser. vol. xxvii. p. 241. Report Brit. Assoc. 1843. Several interesting communications on the coal-plants and the coal-measures may be found in these valuable Reports; for instance, Mr. Buddle's Report on the Newcastle Coal-measures, in the volume for 1838; Mr. Milne on the Berwick and North Durham Coal-field, 1838; Mr. Binney on the Lancashire Coal-fields, 1842, and by Messrs. Heywood and Williamson, 1837; Lord Greenock and Mr. Craig on the Scotch Coal-fields, 1834 and 1840; &c.

† Geol. Soc. Journ. vol. ii. p. 390. Over the door of the room containing the fossil vegetables in the British Museum, there is a Stigmaria twenty-six feet long, with numerous rootlets.

‡ See "Fossil Flora of Great Britain;" and Buckland's "Bridgewater Treatise."

ing roots of the great water-lilies. Thus far Lindley's hypothetical reference of the Stigmariæ to aquatic plants is partially supported; but Brongniart, Binney, Bowman, King, Brown, Dawson, and others have brought forward good evidence of the majority of the Stigmarian bodies being really the stools and roots of trees.

As there is considerable variety in the form and disposition of the tubercles of the Stigmariæ, it is probable that some of them may be the roots of other trees of the carboniferous deposits, with the stems of which they are associated.*



(*From the Geol. Soc. Journ.* vol. IV. p. 47.)

LIGN. 175.—BASE OF THE STEM OF A TREE WITH STIGMARIAN ROOTS; from Cape Breton. At A, B, C, D, there were portions of a coaly bark.

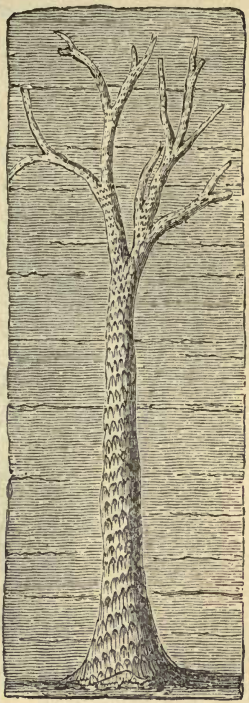
Mr. Richard Brown has described † a rooted stem (*Lign.* 175), found by him in the Coal-measures of Cape Breton, as that of a *Lepidodendron.* Sir C. Lyell, however, refers it to *Sigillaria.*‡ We must recollect, in this instance, that there are some species which it is difficult to define generically either as Sigillaria, Sagenaria, or Lepidodendron, so similar sometimes are the features presented by the stems, or rather parts of the stems.

* Such as *Sagenaria*, &c. See Gœppert's and Geinitz's Memoirs.

† Quart. Journ. Geol. Soc. vol. iv. p. 47.

‡ Manual, 5th edit p. 370.

38. LEPIDODENDRON.*—This belongs to a tribe of plants which has largely contributed to the formation of the coal-strata, and whose remains rival in number and magnitude the Calamites and Sigillariæ. The name, which signifies *Scaly-tree*, is derived from the imbricated appearance of the surface of the stem, occasioned by the form and arrangement of the little angular imprints or scars left by the removal of the leaf-stalks (*Ligns.* 176, 177). Some of these trees have been found almost entire, from their roots to the topmost branches; as in the example here figured (*Lign.* 176), which was nearly forty feet in length. The foliage consists of simple linear leaves, which are spirally arranged around the stem, and appear to have been shed from the base of the tree with age. The markings produced by the attachment of the leaves are never obliterated. In their external configuration, mode of ramification, and disposition of the leaves, and in some points of their internal structure, these trees accord closely with the *Lycopodiaceæ*, or Club-mosses. These are small herbaceous plants, inhabiting woods and bogs; their leaves are simple and imbricated, that is, lie over each other like scales. Most of them trail on the ground, but a few



LIGN. 176.—LEPIDODENDRON STERNBERGII.

A fossil tree, thirteen and a half feet wide at the base, and thirty-nine feet long.

Such a specimen, but without its outer bark, was discovered in the Bensham coal-seam, in the Jarow coal-field: see the "Fossil Flora," Pl. 203.

* Hooker, Mem. Geol. Surv. vol. ii.; Medals, p. 136.

species are erect; * the tropical forms, which are the largest, do not exceed three feet in height. But notwithstanding this

LIGN. 177.—Fig. 1.—TERMINAL PORTION OF A BRANCH OF LEPIDODENDRON. Coal-shale, Newcastle.

Fig. 2.—Scars of petioles (nat. size).

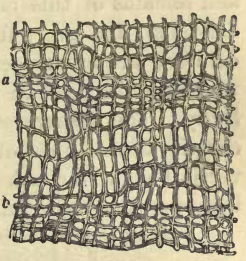
disparity in size, M. Brongniart has shown that the Lepidodendra must be regarded as gigantic plants closely allied to this family. They may be regarded, in fact, as arborescent Lycopodiaceæ, comparable in size to the largest pines; and they formed extensive forests during the carboniferous

* Such as *Lycopodium densum*; Hooker, Mem. Geol. Surv. vol. ii. part 2, p. 423

period, beneath whose shade flourished the lesser ferns and associated plants.

The fruit of the living Club-mosses is an oval or cylindrical cone, which in some species forms an imbricated spike at the extremity of the branches; and there are numerous fossil fruits of this kind found together with the stems and leaves of the Lepidodendra, and in some instances attached to the branches; they have received the name of *Lepidostrobi*, or scaly-cones.*

Besides being preëminently a coal-plant, the *Lepidodendron* is found in the Devonian strata of the United States, of Caithness, and Thuringia; and in the Mountain-limestone of Northumberland.† It occurs also in strata of Carboniferous or Devonian age, both in Australia and South Africa.



LIGN. 178.—Transverse section of a portion of the stem of a recent Pine (*Pinus strobus*,, highly magnified.
a, *b*, Portions of concentric annual layers.

Long narrow branches, covered with numerous small leaves or bracts, occur in the coal-measures, which are regarded as being fossil forms of club-mosses, and are termed *Lycopodites*. Similar plant-remains have been found in the Tertiary and Oolitic strata, and some of these have been correctly referred to the Coniferæ. Indeed, the *Dacrydium cupressinum* of New Zealand, with its long pendant lycopodial branches and regularly scarred stem, and other similar conifers, should remind us that the

* Pict. Atlas, pl. ix. f. 1, and pl. xxxiii.; and Medals of Creation, *Lign.* 40. The structure and affinities of the Lepidostrobi are well worked out and illustrated by Dr. Hooker, in the Mem. Geol. Surv. vol. ii., where Lepidodendron, Sigillariæ, and Calamites, &c., are also made the subjects of elucidation.

† Tate, Fossil Flora of the Mountain Limestone, p. 297.

external form of one family of plants is imitated by another. It is from the fructification that the most decided characters of plants can alone be drawn.

39. CARBONIFEROUS TREES AND PLANTS.*—It was formerly supposed that no vestiges of coniferous plants and trees, which occur so abundantly in the secondary formations, were present in the coal; but Mr. Witham, by microscopical examination, ascertained that trees of this type constituted no inconsiderable portion of the flora of the carboniferous epoch; and remains of this order have since been detected in the Devonian and every formation of later origin. The recent coniferæ are arborescent, dividing into numerous branches, which are disposed in most genera with considerable regularity. The transverse sections of the wood exhibit concentric annual lines of growth (as in *Lign.* 178), and the vertical show the sides of the woody fibres studded with little pores or spots (*Lign.* 179).

LIGN. 179.—Longitudinal section of pine-wood, parallel to a medullary ray; showing the rows of spots or pores.

Some of the fossil trees resemble the European pines in their internal structure: but the greater number belong to the Araucarian type, which is characterized by the rows of spots being disposed, when double, not side by side, as in *Lign.* 179, but alternately, as we have previously explained (p. 713).†

The coniferous trees ‡ of the coal have but few and slight appearances of the lines by which the annual layers are separated, and resemble in this respect the existing species of tropical regions;

* Medals, p. 164, &c.

† In the Royal Gardens at Kew, there are several flourishing trees of the *A. excelsa*, and other kinds of Araucariæ.

‡ Witham, *op. cit.*; and Quekett, Catalog. Foss. Veget. Hunterian Museum, pp. 27 and 28.

we may therefore infer that the seasons of the countries where the coal-plants flourished were subject to but little diversity, and that the changes of temperature were not abrupt.

In a quarry at Craigleith, near Edinburgh, at a depth of 140 feet, part of the trunk of a very large coniferous tree was discovered: its length was thirty-six feet, and the circumference of the base nine feet. Polished sections of this stem beautifully display the coniferous structure. A tree fifty-nine feet long, traversing twelve beds of sandstone, has since been exposed; and, as is commonly the case, the bark was carbonized, and the woody stem was in some parts in the state of sandstone, and in others silicified.

Numerous seed-vessels have been found in the coal-measures, and are known as *Cardiocarpon*, *Rhabdocarpos*, *Carpolites*, and *Trigonocarpon*. The relations of these fruits are mostly very obscure.* The *Trigonocarpa* have been referred by some to palms, and by others to Cycads; but Dr. Hooker has shown † that, although certainly having characters of structure as closely related to the Cycads as to the Conifers, yet it is to the latter that the weight of the evidence tends to refer them; and he especially points to the peculiar coniferous genus *Salisburia* (a native of China), as presenting a fructification similar to that found in *Trigonocarpon*. Dr. Hooker mentions also that, as Dr. Lindley has pointed out, the foliage of Salisburia also affords a modern analogy, for the fossil leaves called Nœggerathia, which, with some Trigonocarpon-like bodies, M. Brongniart has referred to the Cycadaceæ.

Dr. Hooker has described a fragment of cycadeous wood from the Durham coal-field; ‡ and in 1844, M. Gœppert had recognised in the carboniferous rocks of Europe four species of fossil plants which he considered referable to the Cycadaceæ.§

No well-authenticated remains of palms occur in the coal-strata.

* Fiedler; Foss. Frücht. &c. 1857. † Proc. Roy. Soc. vol. vii. p. 28.

‡ Mem. Geol. Survey, vol. ii. part 2, p. 421.

§ Annals Nat. Hist. vol. xv. p. 442. For figures and descriptions of recent and fossil cycadeous plants, see Buckland's Bridg. Treat. p. 494, and Medals, p. 150

40. FLORA OF THE COAL. A more extended notice of the fossil plants of the carboniferous system is not within the scope of these Lectures, and we will now take a brief review of the principal facts that have been submitted to our notice. We have seen that the most remarkable character of the flora of that remote epoch, is the immense numerical ascendance of certain peculiar tribes of cryptogamic plants, which amount to at least two-thirds of the whole of the species

LIGN. 180.—RECENT AND EXTINCT TREES.

Fig. 1. Araucaria (Gymnogen). 2. Pandanus (Endogen). 3. Arborescent Fern (Acrogen). 4. Lepidodendron (fossil).

hitherto determined. With these are associated some coniferæ, a few cycadaceæ, and some rare phanerogamic plants. The vast preponderance and magnitude of the vegetables bearing an analogy to the tribes both of acrogens and of gymnogens, but differing from existing species and genera, constitute,

therefore, the most important botanical feature. Thus we have plants related to the horsetail (*Calamites*), eighteen inches in circumference, and from thirty to forty feet high; arborescent club-mosses (*Lepidodendra*) attaining an altitude of sixty or seventy feet; other great lycopodiaceous trees (*Sigillariæ*) fifty feet in height; besides tree-ferns, and a multitude of minor acotyledonous plants, with comparatively few coniferous trees. The contrast which such a flora presents to that afforded by the woods and forests of dicotyledonous trees, and the verdant turf, which now grow on the surface of the carboniferous districts of England, is as striking as the discrepancy between the zoology of the palæozoic formations and that of the present day. In *Lign.* 180, figs. 1, 3, and 4 represent some of the chief tree-like forms which flourished in the carboniferous era, namely, the coniferous *Araucaria* or Norfolk Island Pine (which is at the present day the best representative we have of some of the woody trees of the Carboniferous and Permian periods), the cryptogamic Tree-fern, and the lycopodiaceous *Lepidodendron* (no longer represented by living species). The Screw-palm or *Pandanus*, introduced in the sketch (*Lign.* 180, fig. 2) as an example of our endogenous tree, appears to have its earliest progenitors in the Jurassic period.

To arrive at any satisfactory conclusions as to the nature of the countries which supported the plants of the coal, we must consider, 1st, the geographical distribution of the related existing genera of plants, and the circumstances which conduce to their full development; and 2ndly, the probable hydrographical conditions of the earth's surface at the coal-period. It is well known that a hot climate, humid atmosphere, and the unvarying temperature of the sea are the circumstances which exert the most favourable influence on the growth of Ferns and other cryptogamic plants; low islands in tropical latitudes being the localities where these forms of vegetation flourish most luxuriantly. From the relative proportion of land and water then probably existing in this region, we may infer that the countries in which the "carboniferous" flora grew were

groups of extensive islands enjoying a subtropical climate.* In the paucity of the gramineæ or grasses, which form so large a proportion of the existing floras, and the predominance of ferns, the vegetation of the coal-measures approached in some respects that of New Zealand, in which the cellulosæ form one-third of the whole, while the grasses are very few in number.†

From the researches of Elie de Beaumont ‡ and Godwin-Austen,§ who have constructed approximative charts of the carboniferous area of Western Europe, we know that the coal-measures and the mountain-limestone were deposited for the most part amongst an extensive archipelago, of which some districts of Scandinavia, Scotland, Ireland, Wales, Cornwall, France, and Northern Italy formed parts.‖ Considerable, but isolated, areas of coal-deposits were formed in lakes on the table-land of what is now Central France; and, according to Mr. Godwin-Austen, equally extensive lake-systems gave origin to the old-red sandstones and conglomerates ¶ of Scotland and Ireland, and probably of that of South Wales also

41. Atmospheric conditions during the Carboniferous epoch. — It appears remarkable that amidst the luxuriant vegetation which prevailed on the dry lands during

* See chap. vii. of Lyell's "Principles of Geology," for the full consideration of probable climatal conditions with given proportions of land and sea.

† See Medals of Creation, vol. i. p. 210; and Lyell's "Principles," p. 87. ‡ See Beudant's *Géologie*.

§ See Quart. Journ. Geol. Soc. vol. xii. pl. i

‖ A very important feature of this old archipelago was a narrow tract of land, or of shoals, reaching from the Franco-Belgian frontier to Somersetshire and the south of Ireland; now recognised chiefly in the Ardennes, on the east, and the Mendips on the west, and by the presence of the elevated and denuded valley of the Weald, and by other geological features along its line. As the coal-measures and the coal-bearing mountain-limestone lie against the flanks of this old transverse ridge, and as it is not covered up by the whole series of the secondary strata, but only by the cretaceous and tertiary series, it is considered probable that coal-beds might be found at much less than 2000 feet below the surface in the neighbourhood of London; especially as coal has already been met with in a deep boring at Calais, on the same line of old rocks. At Harwich, a deep boring has reached this subterranean ridge at about 1000 feet in depth; but it is there composed apparently of rocks older than those of the coal-series.

¶ Quart. Journ. Geol. Soc. vol. xii. p. 51, &c.

the Carboniferous epoch, there should not have existed contemporaneous herbivorous quadrupeds; but not a relic of any animal of this kind has been discovered in the coal-strata. Indeed, with the exception of the Iguanodon of the Wealden (*see* p. 436), no remains of large vegetable feeders * have been found in any of the deposits anterior to the eocene, in which first appear relics of the herbivorous pachyderms. The coal-measures of Nova Scotia alone present vestiges of phytophagous terrestrial mollusca.

It was an opinion once very generally entertained, and the idea still seems to find favour, that previously to and during the Carboniferous period the atmosphere was so charged with carbonic-acid gas as to be unfitted for the respiration of animals of a higher order than reptiles; and that the dense and luxuriant vegetation of that epoch was designed to purify the air, by elaborating coal, and thus abstracting the superabundance of irrespirable gas, and setting free a corresponding proportion of oxygen: thus rendering the surface of the earth suitable for the existence of terrestrial reptiles, and ultimately of birds and mammalia. But Sir C. Lyell has argued that, so far as we know, if any change were induced in the constitution of the atmosphere by such an agency, it would be the reverse of that assumed; for an excess of vegetation would tend to diminish the average amount of carbonic acid, and consequently the air must have been purer than in the succeeding epochs.† It is therefore probable that the absence of herbivorous animals cannot be explained by unfavourable atmospheric conditions: and again we may point to New Zealand as a country having a luxuriant vegetation, yet without herbivorous quadrupeds.‡

42. Formation of Coal-measures.—From the facts which have passed under our examination,§ we may now advantageously consider what were the circumstances which gave rise to these prodigious layers of carbonized matter

* The *Plagiaulax* of Purbeck and the *Stereognathus* of Stonesfield were smaller herbivores. The other known mammals of the secondary period were probably insectivorous.

† Lyell's "Travels in North America," vol. i. p. 152; and "Principles," p. 248.

‡ The only indigenous mammals in New Zealand are one species of *Rat* and another of *Bat;* and there are no large reptiles whatever.

§ See especially p. 681, &c.

unmixed with other materials,—these immense beds of vegetables, from which animal remains are often almost wholly excluded;—and whether accumulations of trees and plants, which in after-ages shall present phenomena of a like nature, are in progress at the present time?

The manner in which the carboniferous strata have been deposited has been a fruitful source of discussion among geologists. Some have contended that the coal-measures were originally peat-bogs, and that the successive layers were occasioned by repeated subsidences of the land;—others, that the vegetable matter originated from rafts, or masses of drifted forest-trees, like those of the Mississippi,* which floated out to sea, and there became ingulfed;—others suppose that they were formed in inland seas or lakes, the materials of the successive beds being brought down by periodical land-floods: and the supporters of each hypothesis adduce numerous facts in corroboration of their respective opinions. There can be no doubt that coal may be, and has been, formed under each of these conditions; and that at different periods, and in different localities, all these causes have been in operation; in some instances singly, and in others in combination. An interesting example of the latter conditions is described by Prof. Dawson, in the *Canadian Naturalist* (October, 1857), as occurring at Pictou, where some portions of the coal-measures present appearances suggestive of "the idea of patches of grey sand rising from a bottom of red mud, with clumps of growing Calamites, which arrested quantities of drift-plants, consisting principally of Sternbergia and fragments of much-decayed wood and bark, now in the state of coaly matter too much penetrated by iron-pyrites to show its structure distinctly. We thus probably have the fresh-growing Calamites, entombed along with the debris of the old decaying Conifers of some neighbouring shore; furnishing an illustration of the truth, that the most ephemeral and perishable forms may be fossilized and preserved contemporaneously with the decay of the most durable tissue. The Rush of a single summer may be preserved with its minutest striæ unharmed, when the giant Pine of centuries has crumbled into mould. It is so now, and it was so equally in the Carboniferous period."

That some of the isolated basins of coal may be carbonized peat-bogs is not improbable, considering that peat often occurs in beds including trees in an erect position, and extending over extensive tracts of country;

* On this river and its branches accumulations of timber, forming rafts 10 miles long, are said to have occurred.—*Lyell's "Principles,"* p. 267.

and in modern peat-bogs (see p. 66) layers are occasionally found having the conchoidal fracture and lustrous appearance of coal.

Other coal-measures may have been accumulated in fresh-water lakes, in estuaries, or in lagoons of fresh or of brackish water, into which the sea made occasional irruptions. To this class would belong the greater proportion of the known coal-measures.

Other carboniferous strata, intercalated with sandstones and limestones containing marine remains in abundance, like those of Russia (see p. 684), must have been deposited in the sea.

The occasional erect position of the stems and the preservation of delicate leaves do not invalidate this inference; for in the rafts formed by the entangled floating forests of the American rivers, trunks of trees frequently occur upright; and in the interior of these rafts grasses and tender plants are often found entire. Such masses, therefore, might be drifted many hundred miles, and yet the imbedded fragile species, protected by the external network of entangled branches, remain uninjured; and, undergoing bituminization, while enveloped by the soft mud permeating the mass, might become changed into durable forms, like those which abound in the natural herbaria of the coal-measures.

The verticality of tree-trunks in some of the strata of the carboniferous series—as, for instance, in the Sandstone of Cragleith, near Edinburgh—may have originated simply from the trees having floated, and been ultimately moored, with their stems upright, or nearly so, in consequence of their roots being loaded with soil. This is a constant occurrence in the great floods of the American rivers; the *snags*, as they are termed, which often render the navigation up the stream difficult and perilous, being formed by drifted trees fixed by their stumps in the river-bottom, and forced into an oblique direction by the current.

Trees in an upright position are often carried out to sea, and have been seen far from land, floating with their topmost branches above the water. Under these circumstances they have been instrumental (like sea-weeds and icebergs, in different degrees) in carrying pebbles and blocks of stone from the land into the deep abysses of the ocean, or to far distant coasts

43. COAL-MEASURES ORIGINATING IN SUBMERGED LANDS. —The theory, so ably advocated by Sir C. Lyell and other eminent geologists, of the formation of coal-measures from repeated submergences and elevations of lands covered with dense forests (see p. 682, 684), seems to be especially applicable to those carboniferous formations which are made up

of regular alternations of coal with beds composed of such earthy materials as render it probable they were once capable of supporting a luxuriant vegetation.

And the fact that the roots (*Stigmariæ*) of the forest-trees (*Sigillariæ*) of the carboniferous period are generally present, and for the most part in their natural position, in the underclay beneath each bed of pure coal, proves that those trees grew on the areas now occupied by their carbonized remains. Without, however, having recourse to the hypothesis of alternate subsidence and elevation of the land, may we not suppose that there were extensive inland areas,* depressed, like the basin of the Caspian, many hundred feet below the level of the sea, affording the shelter, warmth, and moisture required by a subtropical flora, and subjected to

* The most remarkable known instance of an area of land depressed far below the sea-level is that mentioned by Humboldt (*Cosmos*). In descending eastward from Jerusalem to the Dead Sea and the Valley of Jordan, a view is enjoyed which, according to our present hypsometric knowledge of the earth's surface, has no parallel in any other region. The rocks on which the traveller treads, with the open sky over his head, are 1312 feet below the level of the Mediterranean. Though from the revolutions which have swept over the earth's surface, and the displacements and mutations which its crust has undergone since the carboniferous period, there is but little probability that any of the coal-fields are now in the same position in relation to the sea-level as at the period of their formation, I would, nevertheless, direct attention to the following statements and remarks of the illustrious philosopher just cited:—The depth of the Coal-basin at Liege is estimated by Von Dechen at 3809 feet below the surface, and 3464 feet *beneath the level of the sea;* and that of Mons, at 5329: while the lowermost coal-strata of the Saar-Rivier (Saarbrück) are computed by the same eminent observer to descend to a depth of 21,358 feet *below the sea-level*, or 3.6 geographical miles. This is a depth below the sea equal to that of Chimborazo above it; and the temperature would be 467° of Fahrenheit if the increase be in the supposed ratio of 1° for every 54 feet of vertical depth. We have, therefore, from the highest summits of the Himalayahs to the lowest portions of the basins which contain the fossil flora of the carboniferous epoch, a vertical distance of about 48,000 feet, or $\frac{1}{1}\frac{1}{3}\frac{1}{5}$th of the earth's semi-diameter.

periodical inundations from mountain-torrents, poured down from alpine regions on which the pines and other coniferæ, associated with the arborescent ferns of the coal, may have flourished? Would not such physical conditions, modified by occasional changes in the relative level of the land and water by subterranean movements, meet the exigences of the case?

44. Zoophytes and Echinoderms of the Carboniferous System.—We must now briefly notice the animal remains entombed in the deposits that are associated with those which have proved so rich and varied a field of botanical research. The Zoophytes and Molluscs are for the most part marine, and in a great measure confined to the limestones below the coal.

There are but doubtful evidences of the Sponges in these beds; but Foraminifera often abound. *Textularia* and *Endothyra* have been discovered by Prof. Phillips * in slices of limestone from Yorkshire and Westmoreland, and by Mr. Sorby in some mountain-limestone from Shropshire. *Nodoraria* has been found in the carboniferous rocks of Tyrone, by M'Coy;† a Nummulite-like form occurs in the mountain-limestone both of Shropshire and of Russia;‡ and one of the most characteristic fossils of the mountain-limestone of the Lower Volga in Russia,§ and of the Ohio in North America, is the *Fusulina;* white limestones and calcareous shales being almost wholly composed of this little shell (*F. cylindrica*), which resembles a grain of wheat or rice, and is allied to the *Nonioninæ*. A second species has been detected in the carboniferous limestone of the Arctic Regions, by Mr. Salter.‖

* Trans. Polytechn. Soc. Yorkshire, 1846, p. 277.

† Annals Nat. Hist. vol. xiii. p. 131.

‡ Bullet. Imp. Soc. Nat. Moscow, 1849, vol. xxii. p. 337

§ Geology of Russia, Pl. I. fig. 1.

‖ Belcher's "Arctic Voyage," vol. ii. Appendix.

The Corals* amount to very many species, chiefly belonging to the genera *Alveolites*, *Amplexus*, *Aulopora*, *Chætites*, *Clisiophyllum*, *Cyathophyllum*, *Lithodendron*, *Lithostrotion*, *Michelinia*, *Nematophyllum*, *Syringopora*, and *Zaphrentis*.

Of Bryozoa, *Fenestella* is the most common genus in this formation. The mountain-limestone swarms with *Crinoidea;* and entire beds are made up of their petrified remains, as was explained in the former Lecture (see p. 660). Elegant and abundant species of *Actinocrinus*, *Cyathocrinus*, *Platycrinus*, *Poteriocrinus*, and *Rhodocrinus* combine to characterize the carboniferous limestones and shales; but several of rarer occurrence are also found.

A singular type of Crinoideans, named *Pentremites*† (*Lign.* 181, *fig.* 7), also abounds in the mountain-limestone, both in England and America‡ (see p. 666).

Other echinoderms of a peculiar character (*Archæocidaris* and *Palæchinus*) are not unfrequent in the carboniferous limestone of Ireland and Yorkshire.

45. SHELLS OF THE CARBONIFEROUS SYSTEM. — The remains of nearly 800 species of the various tribes of mollusca have been obtained from this formation in the British Isles alone.

About twenty species of bivalve shells, having close alliances with existing genera of shells living in fresh or brackish waters, and therefore indicative of their own fresh-water or estuarine origin, occur in some of the coal-measures. These fossil genera comprise *Anthracosia*,§ *Cardinia*, *Myalina*, *Mytilus*, and *Unio;* and some of the species abound in some parts of the coal-measures in extensive, though thin, beds of shale or limestone, known as "mussel-bands."

* See Milne-Edwards and J. Haime's beautiful Monograph, published by the Palæontographical Society, 1852.

† Comprised in the Blastoidean Order of the Echinodermata.

‡ Medals of Creation, vol. i. p. 297.

§ See Prof. King's interesting paper on the distinctive characters of this member of the Unionidæ, in the Annals Nat. Hist. 2nd ser. vol. xvii. p. 51.

The marine shells of the carboniferous rocks are in a great measure limited to the limestone and shales below the coal. Exceptional instances, however, have been already mentioned.* Many species of gasteropodous spiral univalves abound in some of the limestones. *Pleurotomaria* and *Euomphalus* are the most frequent; the latter is remarkable from its inner volutions being traversed by imperforate septa.† Some limpet-like gasteropods are also found, such as *Capulus* and *Patella*. A very common and characteristic univalve is the *Bellerophon* ‡ (*Lign.* 181, *fig.* 4), usually referred to the Nucleobranchiate division of the Gasteropoda.§

The most interesting Gasteropod of the coal-series is a pupa-like shell, probably a land-snail, of which one or two specimens were found, together with the remains of a little batrachian reptile, by Sir C. Lyell and Mr. Dawson, in an upright fossil tree-stump in the coal-measures of Nova-Scotia.‖ The cephalopodous shells found in the mountain-limestone of Britain and Ireland, and in the associated strata, amount to upwards of 130 species. The Ammonite of the secondary formations is in this system abundantly represented by its near ally, the *Goniatites;* ¶ and the *Nautilus* ** and the *Orthoceras* †† almost rival the Goniatite in numbers.

The *Orthoceras* (*Lign.* 181, *fig.* 12) may be described as a straight Nautilus, of an elongated and cylindrical shape, tapering to the extremity, and having entire septa, pierced by a siphuncule (*fig.* 13). The Orthoceratites are often from twenty to thirty inches in circumference at the largest extremity, and upwards of seven feet in length.

Numerous bivalves of genera closely related to, if not identical with, the existing *Avicula* and *Pecten* also occur; and other bivalves, such as *Cypricardia*, *Conocardium*, *Ed-*

* See above, p. 676. † Medals, p. 428. ‡ Medals, p. 465.
§ Woodward's "Manual of the Mollusca," p. 201.
‖ Quart. Journ. Geol. Soc. vol. ix. p. 58, pl. iv.
¶ Medals, p. 482. ** Medals, p. 467. †† Medals, p. 475.

mondia, Leda, Modiola, Nucula, Sanguinolites, and *Sedgwickia.*

But the most striking modification in the molluscous fauna is the abundance of extinct types of *Brachiopoda* * or *Palliobranchiata,*† such as *Athyris, Chonetes, Leptæna, Lingula, Orthis, Productus, Rhynchonella, Spirifer, Strophomena,* &c. These occur in profusion; and entire beds of limestone sometimes are aggregations of the shells of these curious animals.

As we descend to the more ancient rocks, we shall find these fossils yet more prevalent; and I will, therefore, in this place offer a few remarks on the structure of this family of mollusca.‡ The small subglobular bivalves, *Terebratulæ,*§ so abundant in the chalk, are sometimes found empty, and, if the valves be carefully separated, two curious appendages are seen projecting from the hinge into the interior of the shell; these processes are the internal skeleton for the support of ciliated organs for the production of currents in the water. In the Spirifers (*Lign.* 181, *figs.* 2, 9, 11), there are two spiral appendages ‖ which are closely coiled, and are often, like the substance of the shell itself, changed into calcareous spar (*figs.* 2, 9); in specimens where the shell is removed, these organs may be seen in their original situation.

The loop-like processes observable in the interior of the shells of many of the fossil Terebratulæ are the internal skeleton, and are for the attachment of the muscular stems, or stalks of the fringed arms, or lateral prolongations of the lips of the animal. These arms, or oral appendages, are fringed with *cirrhi,* probably covered with microscopic *cilia;* and by the vibratile action of the latter minute particles of food are transmitted

* *Arm-foot:* the spiral arms of some of these molluscs were at first supposed to serve to some extent as locomotive organs; hence this most-used name.

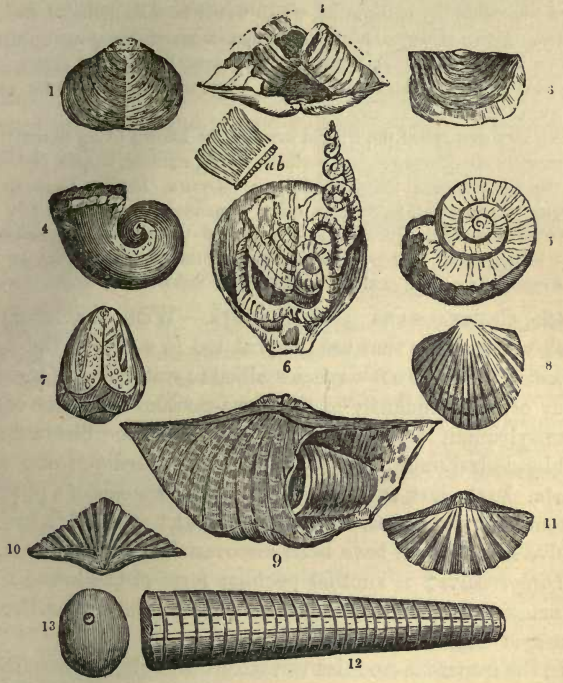
† *Mantle-gilled:* the animals having no special branchiæ or gills, their blood is aërated through the medium of their inner integument or *mantle:* hence this philosophically correct, but neglected name.

‡ See Owen "On the Anatomy of the Brachiopoda," Zoological Transactions, vol. i. p. 145; "Lectures on Comp. Anat." &c.; Woodward's "Manual of Mollusca," p. 209; and Davidson's "Monographs of the British Fossil Brachiopoda," published by the Palæontographical Society (especially the Introduction)

§ Medals, p. 388.

‖ Hence the name of the genus (*coil-bearing*).

towards the mouth. In *Rhynchonella psittacea*, a recent species (*Lign.* 181, *fig.* 6), two spiral arms, fringed at their outer margins, are seen to arise from processes having the form of lamellar plates; these oral arms are quite



LIGN. 181.—SHELLS AND CRINOIDS, CHIEFLY FROM THE PALÆOZOIC STRATA.

Mountain-limestone. Fig. 1. Productus punctatus. 2. Spirifer trigonalis. 4. Cast of Bellerophon cornu-arietis. 5. Euomphalus pentangulatus. 7. Pentremites ellipticus. 9. Spirifer trigonalis, showing one of the spiral processes *in situ*. 10. Spirifer triangularis. 12. Orthoceras laterale. 13. Septum of the same.

Wenlock limestone. Fig. 3. Leptæna depressa. 8. Atrypa reticularis. 11. Spirifer elevatus.

Recent. Fig. 6. Rhynchonella psittacea, showing the fringed spiral brachia or arms, and one of them artificially extended; the perforated valve and the lobe of the mantle are removed. *Fig. a b*, a portion of the fringe of cirrhi, magnified.

free, except at their origins; when unfolded, they are twice as long as the shell, and in their natural state of contraction are disposed in six or

seven spiral gyrations, which decrease towards their extremities. It has been conjectured, that, as the stems are hollow from one end to the other, and filled with fluid, this might be acted upon by the spirally disposed muscles composing the walls of the canal, and forcibly injected towards the extremity of the arms, which would be thus unfolded and protruded. None, however, of the living specimens of this animal observed by Mr. Barrett,* in 1855, protruded their arms; but these organs were extended just so much that the cirrhi, when unbent, came as far as the margin of the shell.

The arrangement of the fringed arms in the known living Brachiopoda is generally either more or less perfectly spiral, sigmoid, looped, or folded. In the fossil genera *Spirifer*, *Athyris*, *Merista*, *Retzia*, *Uncites*, and *Atrypa*, the internal, calcareous, spiral appendages were evidently the supports of perfectly spiral arms. If indeed the arms of *Rhynchonella* were so supported, that genus would present the same structure as that of *Atrypa*, and a close analogy to that of the *Spiriferidæ*.

46. Crustaceans and Insects.—With the layers of fresh-water shells that are intercalated in some of the coal-deposits, there are a few species allied to water-fleas, *Cypridæ*. They occur abundantly in the Nova-Scotian and some of the Pennsylvanian coal-measures; also in the Shrewsbury, Ashby-de-la-Zouch, Border-country, and Burdie-House coal-strata. In the last, and near Glasgow, two species of a peculiar entomostracous crustacean, *Eurypterus*,† one of which is twelve inches long, have been discovered by Dr. Hibbert.

Dithyrocaris ‡ is another peculiar form of the lower tribe of crustaceans not uncommon in some of the carboniferous strata of Ireland and Scotland.

In the ironstone-nodules of Coalbrook Dale, the remains of small crustaceans sometimes form the nucleus, and Mr. Prestwich § discovered some in a good state of preservation (*Lign.* 182). Some of these crustaceans are referable to the *Limu-*

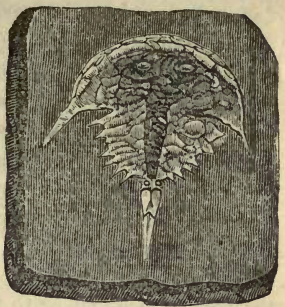
* Annals Nat. Hist. 2nd ser. vol. xvi. p. 257.

† Medals, p. 524. ‡ Medals, p. 525.

‡ Geol. Transact. 2nd ser. vol. v. p. 41.

§ The chemical changes which have taken place in the carboniferous strata, and led to the formation of the bands and nodules of ironstone, are thus explained by Sir H. de la Beche:—The argillaceous

lus, or King-crab; a genus which is abundant in the seas of India and America. The Limulus is one of the lower Crustacea (Entomostraca), and has a distinct carapace or buckler, and the last segment is prolonged into a point or style; it has two eyes in front of the shield, and the gills are disposed on lamelliform processes.



LIGN. 182.—LIMULUS FROM COALBROOK DALE.
*(Limulus trilobitoides.)**

iron-stones are formed of carbonate of iron, mingled mechanically with earthy matter, commonly corresponding with that constituting the shales with which they are associated. Mr. Hunt, of the Museum of Economic Geology, instituted a series of experiments to illustrate the production of these clay-ironstones, and he found that decomposing vegetable matter prevented the further oxidation of the protosalts of iron, and converted the peroxide into protoxide of iron, by taking a portion of its oxygen to form carbonic acid. Under the conditions necessary for the production of the coal distributed among the sand, silt, and mud, the decomposition of the vegetable matter would necessarily form carbonic acid, among other products. This carbonic acid, mixed with water, would spread with it over areas of different dimensions according to circumstances; forming salts and meeting with the protoxide of iron in solution, it would unite with the protoxide, and form a carbonate of iron. The carbonate of iron in solution would mingle with any fine detritus which might be held in mechanical suspension in the same water; and hence, when the conditions for its deposit arose,—which would happen when the needful excess of carbonic acid was removed,—the carbonate of iron would be thrown down, intermingled with the mud; and, if not in sufficient quantity to form continuous layers, would aggregate into nodules, and be arranged in planes amid the sediment.—*Memoirs of the Geological Survey of Great Britain*, vol. i. p. 185. See also Prof. W. Rogers on the Carbonate of Iron in the Coal-Measures, Silliman's Journal, vol. xxi. p. 339; Mr. Binney on the Origin of Iron-stones, Mem. Lit. Phil. Soc. Manchester, vol. xii. p. 31; and a paper by Dr. Hooker and Mr. Binney on some limestone-nodules, in the bituminous coal of the Lancashire coal-field; Proceed. Roy. Soc. vol. xii. p. 188.

* Buckland, Bridg. Treat. p. 396.

It is in the carboniferous system that we first meet, in a descending order, with vestiges of the extinct family of crustaceans called Trilobites* (*Griffithides*, *Phillipsia*, &c.); but, as these animals are especially characteristic of the older rocks—the Silurian, I shall reserve a particular notice of them for the next discourse.

The higher Crustacea are still but little known in the coal-rocks. The *Gampsonyx*,† however, of the Saarbrück coal, combines some characters now found in the Amphipods and the Decapods; and the *Pygocephalus* ‡ of the Manchester coal-shales, another rare form, is referable either to the lower Decapods or to the Stomapods.

Insects.—The remains of insects belonging to several genera have been found in the carboniferous series of England and Europe. From the ironstone-nodules of Coalbrook Dale, several species of beetles, related to the *Curculio* or diamond-beetle, have been obtained. In a nodule from the same locality I discovered the wing of a large neuropterous insect, closely resembling a species of living Corydalis of Carolina.§ The coal-measures of South Wales have also yielded insect-remains.‖

Numerous specimens of orthopterous, neuropterous, and coleopterous insects have been described by F. Goldenberg ¶ from the coal-basin of Saarbrück, in Rhenish Prussia, whence so many other interesting fossils have been obtained.

Fossil Scorpion.—Not only are the remains of insects imbedded in the coal-strata, but also those of animals to which they served as food. A fossil *Scorpion* has been discovered by Count Sternberg in carboniferous argilla-

* Medals, p. 532.

† Jordan and von Meyer, Palæontographica, vol. iv. p. 1, pl. i.

‡ Huxley, Journ. Geol. Soc. vol. xiii. p. 363, pl. xiii.

§ Medals, p. 554. This specimen is now in the British Museum.

‖ In the collection of the Rev. S. Lucas, F.G.S.

¶ Palæontographica, vol. iv. p. 17, plates iii. to vi.

ceous schist, at Chomle, S.W. of Prague, in Bohemia.* This fossil is about two inches and a half long, and is imbedded in coal-shale, with leaves and fruits. The legs, claws, jaws, and teeth, skin, hairs, and even portions of the trachea, or breathing apparatus, are preserved. It has twelve eyes, and all the sockets remain; one of the small eyes and the left large eye retain their form, and have the cornea, or outer skin, preserved in a corrugated or shrivelled state. The horny covering is also preserved; it is neither carbonized nor decomposed, the peculiar substance of which it consists, *elytrine*, having resisted decomposition and mineralization.

47. FISHES OF THE CARBONIFEROUS SYSTEM.—The fishes of the coal† are of the placoid and ganoid groups (see p. 352): and several of the genera have not been found in any other system; all of these have the heterocercal form of tail (see p. 531). Sixty genera have been determined from the carboniferous strata of the British Isles. I can only allude to a few of the most characteristic.

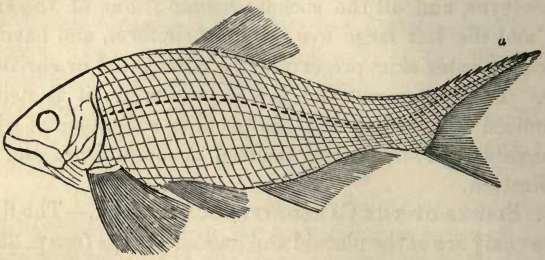
Amblypterus.—This is a genus restricted to the coal-measures, and is characterized, as its name implies, by very large and wide fins composed of numerous rays. The scales are rhomboidal and finely enamelled; and the teeth are small, numerous, and set close together like the hairs of a brush; indicating that these fishes fed on decayed seaweeds and soft animal substances. The tail is a good example of the heterocercal type. A restored outline of the fish is given in *Lign.* 183, from M. Agassiz's great work, the "Poissons Fossiles." Four species have been found in no-

* See Verhandl. Gesell. vat. Mus. Böhmen, 1835, p. 35; Dr. Buckland's Bridgewater Treatise, plate 46, p. 406, *et seq.*

† See some interesting remarks on the fishes of the North American coal-beds, by Mr. Newberry, in the Edinb. New Phil. Journ. New series, vol. v. p. 364; and by Messrs. Worthen and Agassiz, *ibid.* p. 367.

dules of ironstone at Saarbrück, on the borders of Lorraine; and at Newhaven, near Leith.

Megalichthys.—Of the remarkable group of fishes termed *Sauroid*,* the remains of two genera have been discovered in the strata at Burdie House by Dr. Hibbert, and subse-



LION. 183.—RESTORED FIGURE OF THE AMBLYPTERUS; A HETEROCERCAL FISH PECULIAR TO THE CARBONIFEROUS SYSTEM: *one-sixth the nat. size.*

a, The upper lobe of the tail, into which the vertebral column is prolonged.

quently in several other localities. The *Megalichthys* was covered with enamelled, quadrangular, finely granulated scales, very thick, and nearly an inch wide. The head was protected by strong enamelled plates. It had very large teeth, which were conical, hollow, and striated. This fish was from three to four feet in length.

Holoptychius.—This is a genus of gigantic sauroid fishes, some species of which attained a length of thirty feet. The scales are thin and nearly circular, the upper surface corrugated in ridges, and from one to five inches in diameter. The plates covering the head have a shagreen-surface with irregular ridges. It has large conical sauroid teeth of great density; and numerous long slender teeth.

Cestracionts.†—Remains of numerous extinct species of

* Medals, p. 615. † Medals, p. 583.

fishes related to the recent Cestracion, or Port Jackson shark, are found in some beds of the mountain-limestone, especially near Bristol, and at Armagh, in Ireland. At the latter place Admiral Theobald Jones has collected vast numbers of beautiful specimens of teeth (both of the cutting and the crushing forms), and of fin-bones or spines from the hard grey marble; some of them being of large size.*

48. REPTILES OF THE CARBONIFEROUS PERIOD.—Not many years since, reptilian remains not having been then found in the carboniferous rocks, it was supposed that the earliest date of the existence of reptiles on this earth was that of the Permian rocks. Now, however, we have both bones and foot-tracks of reptiles not only in the coal-measures and in the mountain-limestone, but in the Devonian strata.

The *Archegosaurus*,† a sauro-batrachian of close relationship with the *Labyrinthodon* (see p. 552), has left abundant remains in the coal-fields of Rhenish Prussia,‡ the *Parabatrachus* § occurs in the coal of Scotland; and the allied *Dendrerpeton*,‖ and the labyrinthodontoid *Baphetes*,¶ have been found in the coal-measures of Nova Scotia.

Cheirotherian foot-tracks of reptiles have been discovered on some of the shales of the coal-measures in the United States;** and in the red shales at Pottsville, Pennsylvania, which Dr. Isaac Lea refers to the carboniferous series, but which the State-geologists, the Professors W. B. and H. D.

* A very magnificent series of these fossils has been presented to the Geological Society's Museum, by Admiral Jones, F.G.S.

† Medals, p. 745.

‡ See Hermann von Meyer's elaborate Memoir on the Archegosauri and allied genera, in the *Palæontographica*, vol. vi.

Quart. Journ. Geol. Soc. vol. ix. p. 67.

‖ *Ibid.* p. 58; and Lyell's Manual, 5th edit. p. 405; Medals, p. 746.

¶ Quart. Journ. Geol. Soc. vol. x. p. 207, and vol. xi. p. 8.

** See above, p 570; and Lyell's Manual, 5th edit. p. 401.

Rogers, determine to be the local representative of the lower portion of the Mountain-limestone, both Dr. Lea and Prof. H. D. Rogers have found foot-tracks resembling those of thin-toed saurians.*

Similar tracks to the last mentioned have been found on the coal-shale of the Forest of Deane; and Cheirotherian footprints on a gritty carbonaceous stratum, forming a "roof" of the coal, in one of the coal-mines at Dalkeith,† which are worked in the Mountain-limestone series.

Here then are evidences enough, and doubtlessly further researches will contribute more, of the terrestrial and amphibious vertebrated animals, which, crawling among the tangled swampy jungles, and on the oozy surface of the shores, inhabited the lands that were clothed with the luxuriant vegetation of the carboniferous flora.

49. CLIMATE OF THE PALÆOZOIC AGES.—The cause of the difference between the natural climates now prevailing over extensive zones of the earth's surface, and those which the organic remains discovered in many of the older strata lead us to conclude have formerly subsisted during very long periods of time—and apparently over the greater part of its whole extent—is one of those geological problems the solution of which is not at present wholly within our reach. Unable to account for such a distribution of an apparently high climatorial temperature—a diffusion of heat and light so greatly at variance with that which has prevailed during the human epoch—the mind naturally endeavours to penetrate the mystery by a reference to physical causes extraneous to our planet. But, as yet, astronomy has afforded no satisfactory elucidation of the subject.

A variation in the eccentricity of the earth's orbit, and a change in the position of the tropical zone, on account of the precession of the equinox

* *Sauropus primævus*, Lea, Transact. Amer. Phil. Soc. vol. x. 1852.

† Hugh Miller's Testimony of the Rocks, p. 78. These specimens are deposited in the Museum of the Geological Survey, in Jermyn Street.

—both changes, which, though extremely slow, are appreciable—have been brought forward to account for the phenomena under review.

From the diminution of the eccentricity of the earth's orbit round the sun, by which the ellipse is in state of approach to a circle, the annual average of solar radiation is on the decrease; and therefore, as a general cause, and one affecting the mean temperature of the whole globe, and the effect of which is both inevitable and susceptible of exact estimation, it is deserving consideration.*

In assuming a temperature in northern regions sufficient to support a quasi-tropical vegetation, it must, too, be borne in mind, that light is as indispensable as heat for the luxuriant growth of tree-ferns, conifers, cycadeæ, &c.; and, by analogy, for the gigantic club-mosses and ferns of the carboniferous period. The absence of light for weeks or months would probably be fatal to most of the existing tropical forms of vegetation. It is therefore as necessary to account for the presence of light as for a high temperature in the northern regions, where fossil plants indicate the former genial influence of a warm climate and sunny skies during the carboniferous era.

To account for the existence of regions capable of supporting such a flora as that of the coal-measures in northern latitudes, it has been argued by an American author,† that the changes on the earth's surface which have produced the successive strata and organic remains, as far as these are regular, are attributable to the progress of the perihelion point around the ecliptic: that by the precession of the equinoxes, and the progress of the perihelion-rotation of the earth's orbit, a great uniform zone of tropical climate, which formerly surrounded the globe in a different course from that of the present tropics, has by very slow degrees changed its position, and that the present tropical zone succeeds it in a continued change of position.‡

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* Sir J. F. W. Herschel, on the Astronomical Causes which may influence Geological Phenomena. Geol. Trans. 2nd ser. vol. iii. p. 293.

† "An Essay on Organic Remains as connected with an ancient Tropical Region of the Earth." By T. Gilpin, Philadelphia, 1843.

‡ The subject of hypothetical causes of conditions and changes of temperature in former periods of the earth's history has been also treated of by the late Mr. W. D. Saull, in his "Essay on the Connexion between Astronomical and Geological Phenomena," 8vo, London, 1853; and by Mr. Evan Hopkins, in his book entitled, "On the Connexion of Geology with Terrestrial Magnetism." 8vo, London, 1851.

Whether either or both of the above-named causes may be regarded as applicable or adequate to have produced any of the contemplated effects, I must leave to the astronomers to determine. There is, however, another cause, first suggested by Sir C. Lyell, that possesses all the essential requisites of a *vera causa;* and that is the varying influence of the distribution of land and sea over the surface of the earth.*

A change of such distribution in the lapse of ages, by the degradation of the old lands, and the elevation of new, is a demonstrated fact; and the influence of such a change on the climates of particular regions, if not of the whole globe, is a perfectly fair conclusion, from what we know of continental, insular, and oceanic climates by actual observation. "Here, then," observes Sir John Herschel, "we have, at least, a cause on which a philosopher may consent to reason; though whether the changes actually going on are such as to warrant the whole extent of the conclusion, or are even taking place in the right direction, may be considered as undecided, until the matter has been more thoroughly examined." † Another astronomical source of periodical variability in the general temperature of the earth's surface has been brought forward by Sir John Herschel,‡ who, instancing the observed variability in the luminosity of certain stars, suggests the possibility that the sun of our system may in the course of ages be subject to similar phases of augmented or diminished energy; and that such variability in the periods contemplated by Geology may have given rise at one epoch to a general equatorial climate, and at another to one far below the general temperature that now prevails.

Two other supposed causes of the existence of a general warm climate in the earlier geological periods may be here mentioned: namely, 1. *Central heat*, supposed to be the remains of a former and very much greater heat, which has been gradually diminishing during some indefinite period of time: 2. The passage of the solar system through some region

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* Highly important remarks on the relative extent of land and sea in the palæozoic ages were found in the 18th chapter of Sir Roderick Murchison's "Siluria."

† "Discourse on the Study of Natural Philosophy," p. 146.

‡ In his magnificent work, entitled, "Result of Astronomical Observations made at the Cape of Good Hope," 1847, p. 351.

of stellar space, of which the temperature, owing to stellar radiation, is much greater than that in which it is now placed.

Both of these hypotheses have been treated, especially in reference to the Glacial period in the Tertiary age, in a masterly manner by Mr. W. Hopkins, of Cambridge, in the Geological Society's Journal.* With regard to the first, he remarks, that the effect on the superficial temperature due to this cause may have been formerly of any amount, but is now reduced to within 1-20th of a degree of Fahrenheit of that ultimate limit to which it would be reduced in an indefinite period of time, supposing the external conditions under which the earth is now placed—such as the amount of radiation from the sun and stars, and the state of the atmosphere—to remain as at present. Poisson has calculated that it would require 100,000 millions of years to reduce the present temperature by about 1-40th of a degree of Fahrenheit. It is probable, therefore, that many millions of years must have elapsed since the central heat can have elevated the earth's superficial temperature by a single degree, and it is only to the more remote geological periods that we can refer for any very sensible change in the climatal conditions of our globe due to this cause. Prof. Ramsay, following out this line of argument, has shown † that the internal heat of the earth has exerted no important climatal influence during any of the geological periods, from the Silurian times downwards.

Of the second hypothesis, which was suggested by Poisson, Mr. Hopkins remarks that it involves the necessity of supposing a totally different distribution of the group of stars to which the sun should belong, or the near approach of the solar system to some individual star; either supposition being probably inconsistent with the integrity of the solar system as it now exists. At all events, this hypothesis would not account for the changes of climatal temperature that have taken place in comparatively late geological times.

The soundness of the theoretical views of the probable causes of climatal changes suggested by Lyell is well elucidated by Mr. W. Hopkins, in the Memoir above quoted, by an exposition of the probable configuration of the European and North American areas in the Glacial period;—when, according to Mr. Hopkins, the absence of the Gulf-stream, with its influences upon the western coast of Europe, may be assumed,

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* See his Memoir, "On the Causes of Change in the Earth's Superficial Temperature," Journ. Geol. Soc. vol. viii. p. 56; and his Presidential Address for 1852, *ibid.* p. lvii.

† Quart. Journ. Geol. Soc. vol. xi. p. 203.

together with the submergence beneath the sea of a large portion of Northern and Western Europe.*

50. RETROSPECT; BOTANICAL EPOCHS.—I will conclude this discourse with a review of the prevailing botanical characters during the principal geological epochs.

Count Sternberg, M. Adolphe Brongniart, Dr. Lindley, and other eminent botanists have adduced some interesting generalizations from the fossil floras of the various formations: and although conclusions of this kind must be regarded in the nature of shifting hypotheses, and will require to be modified by new discoveries—for all the fossil species at present known amount only to about two thousand,† yet the characters of the floras of certain formations differ in so striking a manner from those of others, that it is very improbable that many of the essential features have been lost.

The flora of the ancient world may be regarded as characteristic of three distinct eras. The first period, termed by Brongniart "the age of Acrogens," comprehends the earliest strata in which traces of vegetation appear,‡ and includes the Carboniferous. The plants of this epoch consist of fucoids, ferns of various kinds in great abundance, coniferous trees related to species of warm climates, cycadaceæ, a few flowering plants,§

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* See also A. Henfrey's "Vegetation of Europe," for some valuable remarks on this subject.

† Prof. Göppert, in 1845 (Rep. Brit. Assoc.), computed the number of species of fossil plants then known to amount to nearly 2000; and stated their distribution in the strata to be as follows:—

In the palæozoic strata below the Coal, principally in the Devonian	52	Triassic	86
Carboniferous	819	Oolitic	234
Permian	58	Wealden	16
		Cretaceous	62
		Tertiary	454

‡ Lycopodiaceous seed-vessels and fragments of wood, found in the Upper Silurian Tilestones, are the oldest-known *terrestrial* plant-remains. —H. E. Strickland, *Quart. Journ. Geol. Soc.* vol. ix. p. 10; and J. W. Salter, *ibid.* vol. xiv. p. 76.

§ The *Antholites* of the coal-measures. Some, at least, of these may have belonged to monocotyledonous, or even dicotyledonous, flowering plants, such as the Bromeliaceæ or the Lobeliaceæ. See Lindley and

great woody equisetaceæ, gigantic lycopodiaceæ, and trees (Sigillariæ) whose precise relations to known forms is not determined. In this flora the tree-ferns predominate, and the general type of the vegetation is analogous to that of the islands and archipelagos of tropical and subtropical climates

The second period (that of Gymnosperms) extends from the Triassic or New Red to the Chalk inclusive, and is characterized by the occurrence of many species of cycadaceæ and coniferæ, a few palms, and, in the Lias,* of a few, but in the Cretaceous beds (see vol. i. p. 329) of many, dicotyledonous plants; while the proportion of ferns is much less than in the preceding period, and the lycopodiaceæ and equisetaceæ are fewer, and present forms different to those of the carboniferous strata. A flora of this nature corresponds with that of the coasts and maritime districts of New Holland and the Cape of Good Hope.

The third epoch (Brongniart's "age of Angiosperms") is that of the tertiary, in which the dicotyledonous tribes present themselves in great abundance; the cycadaceæ are rare, the ferns in diminished numbers, and the coniferæ and palms numerous.

In the latest tertiary strata are imbedded the remains of trees and plants of species still living in the countries where these deposits occur; and so also in the beds in actual progress of formation, the most delicate vegetable remains are preserved; thus, in the lacustrine marls of Scotland the leaves and seed-vessels of the Charæ are found in a state of fossilization scarcely distinguishable from the gyrogonites of the tertiary strata of the Paris basin, and of Headon Hill, or of the Purbeck beds of Dorsetshire.

From this review of the botanical epochs which the present state of geological knowledge enables us to establish, we perceive that, from the most ancient formation in which traces of vegetation remain, the sea has supported the usual forms of marine plants; and that on the land, ferns, other cryptogamia, and coniferæ have existed through periods of indefinite duration to the present time; the most striking and important differences in the ancient and modern floras being the numerical preponderance of the cryptogamia in

Hutton's "Fossil Flora;" Morris, in Prestwich's Memoir on Coalbrook Dale, Geol. Trans. 2nd ser. vol. v.; and Hooker, in Lyell's "Manual" (Supplem. 1857).

* Buckman, Quart. Journ. Geol. Soc. vol. vi. p. 517.

the former, and of the dicotyledonous tribes in the latter,—and the more extensive geographical range of the same species of plants during the Carboniferous era. The theory of the progressive development of creation receives no support from the state of vegetation in the early geological epochs; not only the most perfectly organized of the cryptogamic class, but the coniferæ * also are among the oldest of fossil plants.

The absence of nearly all vegetable forms in the most ancient fossiliferous rocks must not be regarded as a proof that the floras of those remote periods were thus sterile; the only legitimate inference, in the present state of our knowledge, is, that the circumstances under which those strata were accumulated were unfavourable to the envelopment and preservation of terrestrial plants. We have seen that the grand fundamental distinctions of the vegetable kingdom existed in the early secondary ages, a fact in accordance with what we observed in the animal kingdom: and thus the same unity of purpose and design is manifest in all the varied forms of organization that lived on our planet through the vast periods of time which geological investigations have enabled us to scan.

* See Dr. Hooker's opinion of the rank of conifers in the vegetable kingdom, Lyell's "Manual," 5th edit. p. 373.

LECTURE VIII.

PART I.—THE DEVONIAN, SILURIAN, AND CAMBRIAN FORMATIONS.

1. Introductory. 2. The Devonian Series. 3. Subdivisions of the Devonian Series,—Herefordshire and Ireland. 4. Devonian Strata of Devonshire and Cornwall. 5. Devonian Strata of Scotland. 6. Devonian Strata of the Continent and America. 7. Organic Remains of the Devonian Series,—Plants, Zoophytes, Molluscs. 8. Devonian Crustaceans. 9. Devonian Fishes and Reptiles. 10. The Silurian and Cambrian Rocks. 11. Silurian and Cambrian Strata of the British Isles. 12. The Longmynd or Bottom Rocks. 13. Silurian Strata of Staffordshire. 14. The Clent Hills. 15. The Wrekin. 16. The Malvern Hills, &c. 17. Silurian and Cambrian Strata of Europe and America. 18. Silurian Fossils,—Plant-remains. 19. Silurian Zoophytes,—Echinoderms and Annelides. 20. Silurian Molluscs. 21. Silurian Crustacea. 22. Visual Organs of Trilobites. 23. Silurian Fishes. 24. Slate-rocks. 25. Review of the Lower Palæozoic Series.

1. Introductory.—In the previous Lecture the Floras of the palæozoic ages constituted the principal subject of investigation. We examined the primeval forests of coniferæ, the groves of arborescent ferns, and jungles of Sigillariæ and Calamites, which clothed the surface of the soil in that remote period of the earth's physical history. The insects which fluttered among the tropical vegetation of the islands and continents of those periods, the reptiles of the swamps, and the fishes and crustaceans which inhabited the seas and rivers, were brought in review before us, and we contemplated their extraordinary forms and organization, as preserved by those natural processes

> "Which turned the ocean-bed to rock,
> And changed its myriad living swarms
> To the marble's veined forms." Mrs. Howitt.

We now advance another stage in our eventful progress; and again we have to investigate deposits that have been

accumulating for innumerable ages in the profound depths of seas fed by rivers and streams charged with the detritus of the countries over which they flowed, and imbedding the remains of the plants and animals that existed at the period of their formation. Again we shall find new forms of existence presented to our notice, differing from, but bearing an analogy to, the inhabitants of the waters which deposited the marine strata of the most ancient beds previously examined, yet altogether dissimilar from those of modern eras. In vain may we seek for the remains of the mammalia of the Tertiary period,—of the molluscs, fishes, and reptiles of the Chalk,—of the colossal oviparous quadrupeds of the country of the Iguanodon,—of the dragon-forms of the Oolite,—of the fish-like lizards of the Lias,—or of the tropical forests of the Carboniferous period,—all have disappeared; and, as the traveller, who ascends to the regions of eternal snow, gradually loses sight of the abodes of man, and of the groves and forests, until he arrives at sterile plains, where a few stunted shrubs alone meet his eye,—and, as he advances, even these are lost, and mosses and lichens remain the only vestiges of organic life,— and these too at length pass away, and he enters the confines of the inorganic kingdom of nature;—in like manner the geologist, who penetrates the secret recesses of the globe, perceives at every step of his progress the existing types of animals and vegetables gradually disappear, while the relics of other creations teem around him; these in their turn vanish from his sight,—other new strange modifications of organic structure supply their place,—these also fade away,—traces of animal and vegetable life become less and less manifest, until they altogether disappear; and he descends to the crystalline rocks, where all evidence of organization is lost, and the granite, like a pall thrown over the relics of the former world, conceals for ever the earliest scenes of the earth's physical drama.

2. THE DEVONIAN SERIES.—I purpose in this division of the present Lecture to consider the characters and relations of the remaining systems of fossiliferous deposits, namely, the *Devonian*, *Silurian*, and *Cambrian*: all the still more deeply seated rocks, so far as our present knowledge extends, being destitute of any traces of organization, whether of the animal or of the vegetable kingdoms.

The Devonian series, formerly called the *Old Red Sandstone* (p. 205), lies immediately beneath the Carboniferous Limestone, and is largely developed in Devonshire and Cornwall, in Pembrokeshire, Monmouthshire, and Herefordshire; in the south-east border of the Grampians, and over a large portion of the north-eastern part of Scotland. In Ireland there are extensive areas of strata of Devonian age, in the north, south, and central districts. This series consists of many alternations of conglomerates, shales, and sandstones, in various states of induration. The conglomerates are formed of quartz-pebbles, water-worn fragments of slate and other rocks, cemented together either by an argillaceous or a silicious paste, coloured more or less deeply red by peroxide of iron. The quartz has been chiefly derived from the vein-stones of the old slate-rocks. These strata have evidently resulted from the degradation of ancient crystalline and schistose rocks; and have been originally accumulated in the state of pebbles, sand, and mud.

In Scotland, where the Devonian series was first characterized by being found to contain many peculiar fossils, and where it is of vast thickness, it will probably always be known by its first name of "Old Red Sandstone." In Devonshire it contains shells of a character intermediate to those of the Silurian, on the one hand, and those of the carboniferous rocks on the other, and none of which are known to occur in Scotland. The Devonian or Old Red strata were therefore identified first, from their geological position, by Sedgwick, Murchison, and Lonsdale.* Subsequently the two first-mentioned of these authors compared the Devonian of Britain with the infracarboniferous rocks of the Rhine.† Lastly, the identification of the group as really one, both by position and organic contents, was established by the survey of Russia, when Sir R. Murchison, Count Keyserling, and M. de Verneuil demonstrated that the ichthyolites of the "Old Red" of Scotland, including many of the

* Geol. Trans. 2nd ser. vol. v. p. 633, and p. 721.

† Geol. Transact. 2nd ser. vol. vi. p. 221.

very same species, and the shells of the Devonian beds of the south of England, are congregated in the same masses of sand and shale.*

Whilst there is no doubt of the marine origin of the coralliferous and shelly Devonian limestones and shales of Devon, Belgium, Germany, and Russia, there is a difference of opinion existing as to whether the Old Red strata of Scotland, Ireland, and Hereford have been accumulated in marine or in fresh water,—along the margins of a sea, or in great lakes.†

The fossils, so far as the British Isles are concerned, do not decide the question. The Old Red fishes may have been inhabitants of rivers and lakes, like their modern allies, the Bony-pikes of the North American waters, and the Bichirs of the Nile. The local abundance of plant-remains merely indicates, in some cases, the close proximity of land; and in others, probably, the presence of weedy shallows. The only shell-like fossil in the Caithness schists is undescribed, and may be either a Posidonomya, a Cyclas, or an Estheria. On the other hand, the peculiar and characteristic crustacean of the Forfarshire flagstones (the Pterygotus) is associated with some marine shells in the "Tilestones" of Lesmahage and Ludlow (the passage-beds between the Silurian and the Old-Red); though in the Yellow Sandstone of Ireland (Upper Devonian or Lower Carboniferous) it accompanies the probably freshwater mollusc, *Anodonta Jukesii*.

Although usually the conglomerates are supposed to have been the result of an agitated sea acting on the lately upheaved slate-rocks, yet Mr. Godwin-Austen regards these great conglomerate-beds as not being more than equivalent to the enormous shingle-deposits of Lake Superior, and refers to the fact that the whole extent of the Old Red series of Great Britain and Ireland is not equal to the area of the North American lakes. The outflow of the fresh water of the hypothetical Old Red lake-system would carry its fishes (which might also have been of estuarine habits) into the sea-deposits of the period; and thus, in Mr. Godwin-Austen's opinion, account for the intermixture of the Scottish fishes with marine shells in the Devonian strata of Russia. In North America, the Catskill or Old Red Sandstone is rich with the characteristic fish-remains, *Holoptychius* and *Asterolepis*, but yields only two kinds of shells,—of the doubtful genus *Cypricardites* (Vanuxem). Important objections to this hypothesis, however, are advanced by Sir Roderick Murchison, in "Siluria."‡

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* See also "Siluria," p. 264.

† See Godwin-Austen's remarks, Quart. Journ. Geol. Soc. vol. xii. p. 51, &c

‡ "Siluria," p. 259, &c.

3. SUBDIVISIONS OF THE DEVONIAN SYSTEM: HEREFORDSHIRE AND IRELAND.—The uppermost beds of this system, for the most part, dip conformably beneath the mountain-limestone, or other members of the carboniferous series, and the lowermost pass into strata that belong to the upper member of the Silurian series. For the convenience of study, the deposits comprised in this formation in Herefordshire and the neighbouring counties are subdivided into two groups:—

I. QUARTZOSE CONGLOMERATES, SANDSTONES, AND SHALES. The sandstones are often either of a deep chocolate-red or greenish colour. The shales partake of the same tints, but are frequently mottled with blotches of red and green. Fishes of the genus *Holoptychius* and plant-remains.

II. FLAGSTONES, SHALES, AND CORNSTONE. Sandy flagstones, with intercalated red and greenish shales, containing irregular bands of concretionary limestone, provincially termed "cornstone.' Abundant remains of *Cephalaspis* and other peculiar fishes.

[This group passes into the Upper Silurian "Tilestones;" reddish, grey, and yellowish shales and fissile sandstones, which were formerly grouped with Devonian strata, but are now recognised as passage-beds between the two series, though most nearly connected, as to their zoological contents, with the Silurian.*]

The total thickness of this system in Herefordshire and South Wales is estimated by Sir R. Murchison at about 9000 feet; and in Brecknockshire it constitutes the loftiest mountains of South Britain.†

The red conglomerates of this system are well displayed on the right bank of the Wye,‡ from Monmouth to Tintern Abbey (*Medals*, p. 865): and the Devonian sandstone and conglomerate form the base of the Mountain-limestone at the embouchure of the Avon, and the central nucleus or axis of the Mendip Hills (p. 522).

* See Quart. Journ. Geol. Soc. vol. xiii. p. 290.

† "Silurian System," p. 170, &c.; and "Siluria," p. 242.

‡ For the section of the Old Red strata of the Wye, see Phillips's "Manual of Geology," 1856, p. 141.

In Ireland there are several straggling exposures of reddish sandstones and conglomerates, in the southern, central, and northern districts.* These sandstones are overlaid at places by the "yellow sandstones" and "carboniferous slates." †

4. DEVONIAN STRATA OF DEVONSHIRE AND CORNWALL. —In the south of Devonshire, in many places dipping northward towards and beneath the anthracitic or culmiferous shales and limestones (p. 697), there is an extensive series of strata composed of green chlorite-slates, alternating with quartzose schists and sandstones, with blue and grey limestones, which pass into, or are associated with, red sandstones and conglomerates. Many of these beds abound in organic remains. These slaty rocks of Devonshire were formerly regarded as belonging to the earliest or most ancient fossiliferous strata—the *Transition rocks*, as they were termed, until the labours of Professor Sedgwick and Sir R. Murchison, aided by the palæontological research of Mr. Lonsdale, ascertained their true position and relations, and the unity of type which prevails in the organic remains of the entire system, in places very distant from each other, and under very dissimilar conditions of mineral character. The Devonian strata of South Devon extend westward into Cornwall, and the beautiful coralline marbles of Bab-

* See Griffith's Geol. Map of Ireland; and the Map accompanying Mr. Godwin-Austen's Memoir in the Geol. Journ. vol. xii. p. 46.

† See Portlock's "Report on Londonderry," &c.; Report Brit. Assoc. 1843, rep. sect. p. 42, and p. 47; *ibid.* 1852, sect. pp. 43, 47, and 51; Mr. Kelly's paper in the Journ. Geol. Soc. Dublin, vol. xii. p. 115; and particularly Portlock's Presid. Address, 1857, Geol. Soc. Journ. vol. xiii. p. 120. To this late summary, by Gen. Portlock, of the labours of geologists among the Carboniferous and Devonian rocks of Ireland, the reader is especially referred for a philosophical review, not only of the relations of these rocks, but of the principles by which geologists should be guided in working out the correlation of presumed equivalent deposits in different districts. See also Austen, Rep. Brit. Assoc. 1838, sect. p. 93.

bicombe, Torquay, &c. (pp. 650 and 652) belong to this formation.

In North Devon* also there are thick series of gritty, sandy, and shaly rocks, coming out from under the black anthraciferous strata of the central district, and presenting many characters in common with the Devonian rocks of South Wales, from which they are separated by the Bristol Channel.

From careful and extended examinations of these rocks and their fossils in North and South Devon and in Cornwall, a serial order has been recognised, according to which the northern and southern bands of strata are more or less uniformly arranged, although great differences in their mineral composition and in the variable abundance or paucity of fossils, and the frequent metamorphic changes the rocks have undergone, have made this a difficult study.†

Beneath the culm-limestones and black shales with *Posidonomyæ*, succeed—

(1.) The *Barnstaple* or *Petherwin* group of strata; chiefly consisting of shales and sandstones, associated with a limestone containing a peculiar cephalopod, the *Clymenia*, of the Nautiloid family. These beds contain numerous plant-remains (*Aspidaria*, &c.), and comprise a series of strata (the Pilton group) which are the equivalents of the "Yellow Sandstones" of Ireland and the Boulonnais. They constitute the beds of passage between the Carboniferous to the Devonian systems, being very closely related by conformability and fossils to the former. This group is equivalent also to the *Cypridinen-schiefer* and *Clymenien-kalk* of Germany.

* See the description of a section across North Devon, in "Siluria," p. 256.

† Sedgwick, Murchison, Lonsdale, Austen, De la Beche, Phillips, Sharpe, Giles, Peach, Pattison, and many others have elucidated these strata and fossils in the publications of the Geological Societies of London and Cornwall, and in other works.

(2.) The *Ilfracomb* or *Plymouth* group, comprising the rich coral-limestones of South Devon: the equivalent of the *Eifelian* group of the Devonian rocks on the Rhine, containing *Stringocephalus Burtini*, *Brontes flabellifer*, and *Calceola sandalina*, as typical fossils.

(3.) The *Linton* or *Ashburton* group; representing the Wissenbach-slates of the Rhine, with *Pleurodictyum problematicum*.

Cornwall principally consists of "Devonian" strata, with metamorphic schists or slates (*killas*), and great masses and numerous dykes (*elvans*) of igneous rocks; but Silurian * or Cambrian † fossils have been detected in the schists and quartzites of two of the southern headlands (Nare Head and the Dodman).

The *killas* are argillaceous strata, probably of "Devonian" age, that have been indurated by metamorphic action, like those of Scandinavia and the Ural Mountains, and, as in those countries, traversed by granites and porphyries. Sir R. Murchison remarks,‡ that the stanniferous (*tin-bearing*) gravels of Cornwall bear the same relation to the granite and killas as the auriferous deposits of the Urals to the erupted and schistose rocks of that chain.

5. DEVONIAN SERIES OR OLD RED OF SCOTLAND.—The deposits of this system occupy an important place in the geology of Scotland. They have of late years attracted considerable attention from the interesting fossils they have yielded, and the admirable illustrations of the most important phenomena given by the late Mr. Hugh Miller in his delightful and instructive works.§ According to this charm-

* Murchison; Transact. Roy. Geol. Soc. Cornwall, vol. vi. p. 317, &c.

† Sedgwick; Quart. Journ. Geol. Soc. vol. viii. p. 1, &c. Jameson's Edinburgh Journal, 1847, vol. xliii. p. 40.

§ It is scarcely necessary to enumerate those of the well-known works of this gifted and lamented writer which more especially refer to his favourite and long-studied group of the "Old Red" strata. The student must necessarily have frequent recourse to the following for

ing writer, the whole of the north-eastern part of Scotland, from the Pentland Frith to the mouth of the River Spey, consists of Devonian deposits resting on a central nucleus of crystalline rocks, viz. granite, gneiss, and micaceous schists. Similar strata are also found in insulated patches in various places of the interior of the country.

South of the Grampians, Devonian strata underlie the Carboniferous strata of Fifeshire; and a zone of these deposits skirts the southern flank of those mountains, from Stonehaven to the Frith of Clyde, and constitutes, with intrusive trap-rocks, the Sidlaw Hills and the Valley of Strathmore.

In a section * of the country from the foot of the Grampians, in Forfarshire, to the sea at Arbroath, a distance of about twenty miles, where the entire mass of strata is several thousand feet thick, a triple division of the Old Red Sandstone is very obvious; namely, 1st, and uppermost, yellowish sandstones, red and mottled shales, cornstone, and sandstone. 2. Conglomerates, often of vast thickness. 3. Tilestones and pavingstones, highly micaceous. The lowermost beds contain remains of grass-like or fucoidal plants in abundance, together with numerous small black patches (*Parka decipiens* of Fleming) resembling crushed blackberries, some of which have been regarded as the catkins of plants resembling rushes or sedges (Sparganium), whilst others have been thought to resemble more nearly the spawn of newts and other animals.†

The following is a general classification of the Devonian rocks of North Britain.‡

Upper or Yellow Group.	Sandstones and shales. Reptiles (*Telerpeton Elginense* and foot-tracks); numerous fishes; some plant-remains. Pebbly grits and sandstone. Remains of fishes and plants

critical information on this interesting series and its fossils:—"The Old Red Sandstone, or New Walks in an Old Field;" "The Footprints of the Creator, or the Asterolepis of Stromness;" and "The Testimony of the Rocks."

* See Lyell's "Manual of Geology," 5th edit. p. 48; and Murchison's "Siluria," p. 248.

† See Quart. Journ. Geol. Soc. vol. viii. p. 106; and Lyell's "Manual of Geology," 5th edit. p. 421.

‡ Page's "Text Book," p. 124; Lyell's "Manual," p. 415, &c. See also Rep. Brit. Assoc. 1855, sect. p. 92.

MIDDLE or Red Group.	Sandstones and conglomerates, with shales and cornstones. (The typical "Old Red" of Cumberland, Fife, Perth, and Forfar.)
LOWER or Grey Group.	Micaceous sandy flagstones, sometimes bituminous; numerous fishes and plants (Caithness); flagstones and tilestones; fishes, crustaceans (*Pterygotus*), and plant-remains (Forfarshire); with sandstones and conglomerates.

The predominating colour of the great sandstones and conglomerates has probably been derived from the debris of the red granitic gneiss which forms chains of precipitous ridges in the north of Scotland. This rock contains hæmatitic iron-ore, diffused as a component of the stone throughout its entire mass; and this metal also occurs in insulated blocks of great richness, and in thin filiform veins.*

6. DEVONIAN ROCKS OF THE CONTINENT AND AMERICA.—On the Continent, Devonian strata are of wide extent.†

They have been well studied in Brittany, the Boulonnais, and Belgium. In Rhenish Prussia and the adjacent districts of Germany, they underlie the carboniferous series, and may be traced around, and dipping under, the coal-field of Westphalia. In the Rhenish Provinces, though the strata are often greatly contorted and broken, and even sometimes inverted or bent back,—the younger lying over the older beds,—yet a perfect and complete succession of groups of Devonian strata have been shown to exist in this region, chiefly by the labours of Sedgwick and Murchison,‡ d'Archiac and De Verneuil, Rœmer, and the brothers Sandberger.

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* Miller's "Old Red Sandstone," p. 248.

† See Murchison and Nicol's Geol. Map of Europe; "Siluria," chapters 10, 13, 14, and 15; and Phillips' "Manual," p. 144.

‡ The important Memoir, "On the Distribution and Classification of the Older or Palæozoic Deposits of the North of Germany and Belgium, and their Comparison with Formations of the same age in the British Isles," by Sedgwick and Murchison, in the Geol. Trans. 2nd ser. vol. vi. p. 221, &c., followed by MM. d'Archiac and De Verneuil's "Descriptions of the Fossils of the Older Deposits in the Rhenish Provinces" (*ibid.* p. 303), was the groundwork for subsequent labours in this field. A full résumé of the subject, enriched with all the corrections and additions made since 1840, and noticing the views of others relative to some discussed points of classification, has been given to the public in Sir R. Murchison's late work on the history of the Palæozoic rocks, "Siluria;" and to this

The general order of the Rhenish Devonian series appears to be, 1st, (uppermost), Cypridina-schists, Clymenia-limestones, and Goniatite-schists; 2. the great Eifel-limestone and Calceola-schist; 3. Wissenbach-schists and the Coblentz-greywacke or Spirifer-sandstone.

In Russia, according to the researches of Sir R. I. Murchison and his colleagues,* the Devonian strata extend over an area of 150,000 square miles, a region more spacious than the British Isles; and yet throughout this vast superficies the series, though of less thickness, is even more distinctly marked by its typical fossils than in the disturbed districts of our own little Island: for the fossil fishes of Old Red schists of Scotland, and the fossil shells of Devonshire and the Eifel, are there found in the same deposits.

In North America, the Devonian deposits appear in a very prominent and characteristic form, surrounding each of the great coal-fields of the United States; and consist of a thick series of shales, sandstones, and flagstones, often rich with Devonian fossils, surmounted by red sandstone, conglomerate, and shales containing remains of some of the peculiar fishes which are so abundant also in the "old red sandstone" of England and Scotland. These Devonian rocks of North America are divided into the following 12 groups, in descending order, the Catskill, Chemung, and Portage groups, Genessee slate, Tully-limestone, Hamilton group, Marcellus-shales, Corniferous and Onondaga limestones, Schoharie and Caudagalli grits, and the Oriskany sandstone. Devonian rocks occur also on the eastern side of the Rocky Mountains, along the great Mackenzie valley.†

Devonian fossils have been found also in South America (D'Orbigny),‡ the Falkland Islands (Darwin),§ Australia (Strezlecki),‖ North and South Africa (Overweg¶ and Bain),** and China.†† In fact, the Devonian rocks are perhaps the most widely spread of all the palæozoic groups.

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standard authority the reader is referred for a full account of the Devonian rocks of Germany and Belgium, and a comparison of these with the Old Red series of Britain and other countries.

* "Geology of Russia in Europe and the Ural."

† Richardson and Isbister, Geol. Soc. Journ. vol. xi. p. 509.

‡ "Voyage dans l'Amerique Méridionale," p. 35.

§ Quart. Journ. Geol. Soc. vol. ii. p. 274.

‖ "Physical Description of New South Wales and Van Diemen's Land: Appendix.

¶ Rep. Brit. Assoc. 1851, sect. p. 58.

** Trans. Geol. Soc. 2nd ser. vol. vii. pp. 182 and 224.

†† Bullet. l'Acad. Belg. vol. xiii. part 2, p. 415. Quart. Journ. Geol. Soc. vol. ix. p. 353; and *ibid.* vol. xii. p. 378.

7. ORGANIC REMAINS OF THE DEVONIAN.—The deposits comprised under the names of the "Old Red" and "Devonian" were formerly regarded as very sterile in organic remains, and classed among the so-called Transition rocks (vol. i. p. 37), in which it was supposed that traces of animal life first appeared. Modern researches, however, have shown that, though many of the strata are locally unproductive in fossils, yet others abound in the remains of corals, shells, crustaceans, and fishes. The marine fauna of this period is extremely rich, containing certain peculiar types, but, as a whole, forming a connecting link between the zoology of the Silurian series, which preceded it, and the Carboniferous, which followed.

Ichthyolites are abundant, and occasionally crustaceans, in some of the sandstones of Caithness, Cromarty, Forfar, Gamrie,* and other localities in Scotland, and in the Old Red Sandstone of Herefordshire; but only very slight traces of shells have been found. In the limestones and schists of Devonshire, on the contrary, shells, corals, crinoids, and trilobites are numerous.

Plants.—Of the vegetable kingdom, many traces are found in the Devonian series; as well as occasional intercalations of thin layers of coal and carbonaceous strata. As a whole, the Devonian flora is nearly related to that of the subsequent Carboniferous period.

The flagstones of Forfarshire abound with impressions of obscure plant-remains, and amongst these are found the blackberry-like fossils, already alluded to under the name of *Parka decipiens* (p. 787). These are groups of small, flattened hexagonal, carbonaceous bodies, occupying slight depressions in the stone; and, according to some observers,† are not always relics of seeds, but frequently are the remains of the spawn of molluscs and batrachians, and even possibly of crustaceans and fishes.

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* Prestwich, Geol. Trans. 2nd ser. vol. v. p. 139.

† Fleming, in Edinb. Journ. Nat. Science, 1831, vol. iii., and in Murchison's "Siluria," p. 266; Mantell, Quart. Journ. Geol. Soc. vol. viii. p. 106; Lyell, Manual, p. 421; Page, Text-book, p. 126.

The flagstones of Caithness and the Orkneys have afforded much more distinct evidences of the Devonian flora. According to Mr. Salter,* we have here the stems and roots of Conifers in abundance, with remains of Lycopodiaceous plants, not altogether dissimilar from some portions of the rich Devonian flora of the Thüringerwald, collected and described by Richter and Unger.†

In the "Yellow Sandstone" of Knocktopher, near Kilkenny, which is usually classed as Upper Devonian, ferns (*Cyclopteris Hibernica*), *Lepidodendron*, *Lepidophyllum*, and *Stigmaria* occur in profusion, associated with remains of *Holoptychius*, *Pterygotus*, and an Anodonta-like shell.‡ In North America also plant-remains are frequent in the Devonian strata, and Lepidodendron occurs low down in the series. Prof. Dawson § has recognised coniferous wood in the Devonian rocks of Gaspé, Canada

Zoophytes, &c.‖ — The Corals and Crinoids are numerous, and many of the genera are found also both in the Silurian and the Carboniferous rocks. *Alveolites*, *Favosites*, and

* Quart. Journ. Geol. Soc. vol. xiv. p. 72. See also Hugh Miller's "Testimony of the Rocks."

† Vienna Acad. Transact. vol. xi.

‡ Report Brit. Assoc. 1852, rep. sect. p. 43. See also Prof. Harkness's paper on the "Occurrence of Scalariform Tissue in the Devonian Rocks of Ireland." Edinb. New Phil. Journ. vol. iv. p. 65.

§ Proceed. Americ. Assoc. 10th meeting, p. 174

‖ For figures and descriptions of the fossil invertebrata of the Palæozoic rocks of Cornwall, Devon, and West Somerset, the student must consult Prof. Phillips's able "Report Pal. Foss.," &c., 1841; and the Memoirs by Sedgwick, Murchison, Lonsdale, and Austen, in the Geol. Transact. 2nd ser. vols. v. vi., &c. The Devonian Corals of Britain form the subject of a beautiful Monograph, by Milne Edwards and Haime, published by the Palæontographical Society, 1853. Agassiz's "Poiss. Foss." and Hugh Miller's "Old Red Sandstone" and other works illustrate the Devonian fishes. The Devonian fossils of Germany may be studied in the special Memoirs by D'Archiac and DeVerneuil, Richter and Unger, Rœmer, the Sandbergers, Geinitz, &c.; those of France are illustrated in many papers in the *Bulletin* and *Mémoires* of the Geological Society of France; and those of Russia have been described by D'Orbigny, and beautifully figured in the "Geol. Russia." Hall, Vanuxem, and others have well illustrated the Devonian fossils of North America. Several Devonian fossils are well figured in Lyell's "Manual," 5th edit., and in Murchison's "Siluria."

Cyathophyllum are common in the Mountain-limestone, the Devonian marbles, and the Upper Silurian of Dudley. The crinoideans comprise several genera, especially *Cyathocrinus* (p. 664) and *Hexacrinus*. *Pentremites* and *Echinosphærites* also occur. The bryozoa also are well represented in the Devonian rocks.

Mollusca.—The shells in some districts are very numerous, consisting of many genera of gasteropoda; as, *Euomphalus*, *Loxonema*, *Pleurotomaria*, *Murchisonia*, &c.; and acephala, as *Avicula*, *Cucullæa*, *Megalodon*, *Nucula*, &c.

But the most remarkable feature in the conchology of this epoch is the abundance of the ancient types of brachiopoda. In the British Devonian strata alone have been determined of *Athyris* 7 species, *Leptæna* 8, *Orthis* 12, *Rhynchonella* 19, and of *Spirifer* 27.

Of the higher order of molluscous animals, species of five genera are met with in Devonshire. The most common belong to *Orthoceras*, *Cyrtoceras*, *Goniatites*,* and *Clymenia*.† The Orthoceratites in the limestones of Devonshire often attain a large size. The shell is commonly changed into white calcareous spar, which in sections forms a beautiful contrast with the red hue of the surrounding rock.‡ Two species of *Nautilus* are found in Devon, and five species of the heteropodous *Bellerophon*.

8. CRUSTACEANS OF THE DEVONIAN SERIES.—In this formation the chief palæozoic type of Crustaceans, the Trilobite, is present in considerable numbers, though not rivalling the myriads that are imbedded in the Silurian rocks.

* Medals, p. 482. † Medals, p. 473.

‡ Polished slices of marble marked with sections of Orthoceratites are sold by the lapidaries of Torquay and Teignmouth. Medals, p. 474. The curious bodies, termed "Beekites," which are found in the New Red Conglomerate of Torquay, appear to have been rolled fossils of the Devonian limestone, which have been coated with chalcedony whilst in the conglomerate, and afterwards decomposed to a greater or less extent. See Rep. Brit. Assoc. 1856, sect. p. 74.

The *Phacops* is a common form; the spinose Homolonoti* are characteristic; and a peculiar trilobite, termed *Brontes flabellifer*, has hitherto been found only in the Devonian deposits.

Pterygotus.—A large species of an extinct genus of crustaceans, of a low type, occurs in the Devonian sandstone of Forfarshire, Herefordshire, &c.; and fragments of the carapace or shell have long been known to collectors as "*petrified Seraphims*," the name applied to these fossils by the quarrymen, from their fancied resemblance to the conventional figures of cherubs.† The first specimens which threw light on the nature of the original were discovered by Mr. Hugh Miller at Balruddery. The carapace of this animal forms a somewhat semicircular shield, and the long part of the body is protected by a succession of transverse plates, terminated by a caudal flap.‡ The claws resemble those of the common lobster. The crustaceous covering, or shell, is ornamented externally with circular and elliptical markings, which give it an imbricated, scaly, and somewhat feathered appearance: and it was the imprints of this surface that produced the enigmatical fossils to which the workmen ascribed a celestial origin! Some specimens in dicate a total length of eight feet.

Pterygotus occurs also in the uppermost of the Silurian deposits; and *Eurypterus*, an allied genus, occurs both in the Upper Silurian and in the Carboniferous rocks. Some of the small bivalvular entomostraca occur also in the Devonian rocks, such as the *Leperditia*;§ and a great group of schists

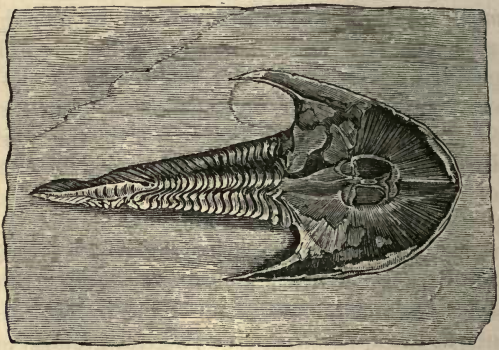
* Lyell's "Manual," p. 429. † Miller's "Old Red Sandstone."

‡ See Lyell's "Manual," 5th edit. p. 420, for a restored figure of this animal, by Prof. M'Coy; and the Quart. Journ. Geol. Soc. vol. xii. p. 28, for a figure of *Himantopterus* (a closely allied form), by Mr. Salter; see also Salter, *ibid.* vol. viii. p. 386, and Agassiz, "Foss. Vieux Grès Rouge," p. xix. By the kind permission of Sir R. Murchison, the Editor can also refer to p. 155 of the new edition of "Siluria," now in the press, for a restored figure of Pterygotus, by Mr. Salter.

§ Annals Nat. Hist. 2nd ser. vol. xviii. p. 89

in the upper part of the series is so full of the shells and casts of entomostraca, hitherto supposed to be *Cypridinæ*, that they are known as the "Cypridinen-schiefer." It is highly probable, however, that these entomostraca will prove to have little or no relation to the *Cypridina* of M. Milne Edwards, when carefully examined by crustaceologists.

9. FISHES AND REPTILES OF THE DEVONIAN SERIES.—M. Agassiz has determined no less than one hundred species of fossil fishes from the Devonian formation, in which, not very many years since, a few doubtful scales, discovered in Forfarshire by the late Dr. Fleming, were the only known vestiges of this class of vertebrated animals. In the British series there are upwards of ninety species, belonging to about thirty-five genera. Of these, the most characteristic



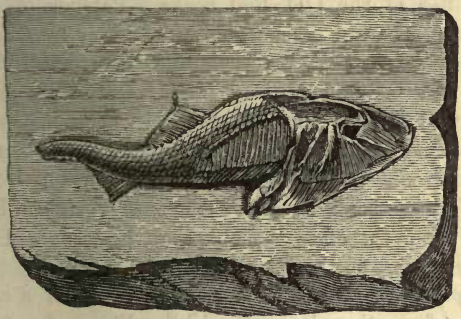
LIGN. 184.—CEPHALASPIS LYELLII.

A flattened specimen showing the dorsal surface. (One-fourth the nat. size.)
From the Devonian strata of Glammis, in Forfarshire.

are the *Cephalaspis*, *Pterichthys*, and *Coccosteus*, which form a group of extinct genera, that have only a few representatives in the uppermost portion of the Silurian formation below, and none in the Carboniferous rocks above; nor, except

by distant and faint analogies with existing fishes, can these remarkable organisms be brought within the pale of zoological arrangement. These ichthyolites agree in one general character, that of having relatively enormous osseous plates or escutcheons covering the head and anterior portion of the body.

*Cephalaspis.**—In the extraordinary genus of fishes, named *Cephalaspis* (*Head-buckler*) by M. Agassiz, the head is covered by a broad and thin buckler or shield of bone.† The scales of the tail formed elevated bands, and the rays of the fins were covered by the membrane which elsewhere surrounded them. From the large size of the plate forming the cover of the head, its lamellar structure, and crescent-like form, terminating backwards in two horns or points, detached specimens were formerly supposed to belong to trilobites or some other crustaceans. The body is covered with scales, and the shield is sometimes ornamented with radiated



Lign. 185.—Cephalaspis Lyellii.
Lateral view, showing the produced dorsal lobe of the tail.

markings, as in *Cephalaspis ornatus* and *C. verrucosus*.‡ Numerous remains of these fishes have been found in the Devonian strata of Herefordshire, Scotland, and Russia. Mr.

* Medals, p. 610. † Huxley; Geol. Proceed. January 6th, 1858
‡ Quart. Journ. Geol. Soc. vol. xiv. p. 48.

Miller states, that in Scotland they are principally restricted to the group of cornstone and marls. Some species occur also in the uppermost Silurian strata.

*Pterichthys.**—The fishes of this genus are distinguished by two wing-like lateral appendages, which, like the spines of the common Bull-head (*Cottus gobio*), were weapons of defence. The head and anterior part of the body are covered with large angular tuberculated scutcheons. There are two eyes, which are placed in front of the lateral spines. Ten species occur in the British strata; mostly not exceeding eight or ten inches in length.

Coccosteus.†—In form, and in the arrangement of the bony scutcheons, the fishes of this genus have a resemblance to the Pterichthys. The plates are tuberculated; the tail is very long, covered with scales, and supports a fin. There are four or five species, varying in length from a few inches to two feet. Their remains are the most abundant of the ichthyolites of the Old Red rocks. Patches of detached scales and separate osseous plates are very frequent in the sandy cornstones and subcrystalline limestones. They are usually of a brilliant blue or purple colour, which, strongly contrasting with the dull red tint of the surrounding rock, renders them easy to be detected. This colour is supposed to be due to the presence of phosphate of iron.‡ In none of these fishes have any traces of vertebræ been discovered; it is therefore probable that the spinal column was cartilaginous, as in the Sturgeon.

Holoptychius.—My limits will only admit of a rapid notice of a few other Devonian ichthyolites. Among these, several species of the large ganoid fishes, named *Holoptychius*,§ from the peculiar character of the scales, are most

* *Wing-fish.* Medals of Creation, p. 612. Miller's "Old Red Sandstone."

† *Berry-boned:* from the plates being studded over with small tubercles. Medals of Creation, p. 614; Miller, *op. cit.*; and "Siluria," p. 252.

‡ "Silurian System," p. 588.

§ *Solid-wrinkled.* A splendid specimen of *H. nobilissimus*, twenty-

strikingly conspicuous. This genus we have already noticed in the account of the carboniferous ichthyolites (p. 770).

Dendrodus.—This fish is allied to the Holoptychius, but the structure of the teeth, scales, and occipital plates is peculiar. The teeth are of a conical form, slightly curved, solid throughout, and finely striated longitudinally; and the calcigerous tubes are so disposed as to produce a dendritical or arborescent appearance in transverse sections; a character which is expressed by the name Dendrodus,* given to the fish by Prof. Owen.

Dipterus and *Diplopterus* are two nearly related genera of ganoid fishes, so named from their possessing two dorsal fins, which are placed opposite the anal and ventral fins. These fishes, together with the *Osteolepis*,† another common Devonian genus, have bony scales plated with enamel and finely punctated; and their jaws consisted of enamel without and bone within, and were beset with sharp-pointed teeth.

Glyptolepis, *Cheirolepis*, and *Cheiracanthus* ‡ are other characteristic fishes of this series of deposits. Of the placoid fishes (p. 352), species of the genera *Onchus* and *Ctenacanthus* have been discovered; but the placoideans are but feebly represented in the Devonian epoch, while the ganoid group is largely developed.

Reptiles.—The most ancient *reptilian* ichnolites or footprints are those discovered by Capt. Brickenden,§ in the Old Red Sandstone of Cummingston, near Elgin, which resemble the track of a Chelonian reptile. But still more in-

eight inches long, is figured in "Silurian System," pl. 2, and is now in the British Museum; "Petrif." p. 434.

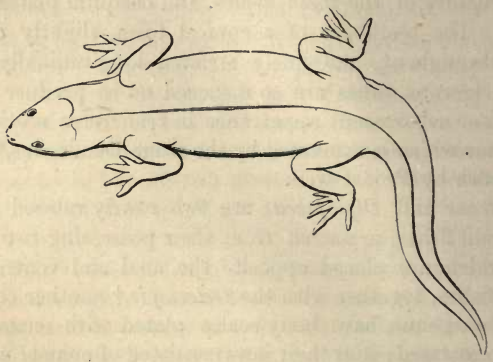
* *Tree-tooth.* Medals of Creation, p. 618, and Pl. VI. fig. 8.

Bony-scale. Miller's "Old Red Sandstone," p. 80; and "Footprints of the Creator," p. 30.

‡ *Carved-scale*, *Hand-scale*, and *Hand-thorn.* Consult Hugh Miller's works above quoted; Agassiz's beautiful Monograph on the Fishes of the Old Red Sandstone; and Murchison's "Silurian System."

§ Quart. Journ. Geol. Soc. vol. viii. p. 97.

teresting evidence of the existence of oviparous quadrupeds in the Devonian period has been afforded by Mr. Duff's dis-



LIGN. 186.—TELERPETON ELGINENSE. From the Old Red Sandstone of Scotland.

Outline of the restored form of the original reptile: one-half the natural size.

covery of the skeleton of a small reptile in the same sandstone, near Elgin, that has yielded the footprints. This is the *Telerpeton Elginense* (Mantell),* a lacertian reptile with batrachian modifications. *Lign.* 186 exhibits, in outline, the probably newt-like shape of this interesting palæozoic reptile, at half the natural size.

10. THE SILURIAN AND CAMBRIAN ROCKS.—By reference to the synoptical arrangement of the formations (p. 205), it will be seen, that the great interval between the hypogene rocks (gneiss and mica-schist), and the Devonian series, as above described, is occupied by an immense thickness of

* Quart. Journ. Geol. Soc. vol. viii. p. 100; and "Medals of Creation," vol. ii. p. 720. This specimen was described, under the name of *Leptopleuron lacertinum*, by Prof. Owen, in the "Literary Gazette," contemporaneously with Dr. Mantell's communication on the subject to the Geological Society.

slate-rocks, limestones, sandstones, and argillaceous strata. These deposits were formerly grouped with some of the Devonian rocks, under the name of *Transition-rocks;* a designation applied by the celebrated Werner upon the supposition that they were formed when the world was in a state of transition from a chaotic to a habitable condition: they were also termed *Grauwacké*,* from the hardened gritty character of many of the strata, but the whole series is now divided into two natural groups. The uppermost has been designated the UPPER SILURIAN,† by Sir R. I. Murchison, whose indefatigable researches have determined the true position, relation, and character of these deposits; the lower group being his LOWER SILURIAN and BOTTOM ROCKS: whilst, by the Rev. Professor Sedgwick, whose successful labours in this difficult field of geological investigation have rendered clear and intelligible many phenomena which were previously involved in doubt and obscurity, the upper group is termed SILURIAN, and the lower one CAMBRIAN.‡

We have here the inconvenience of a double set of terms, which became attached to these important groups of lower palæozoic rocks in this wise. When Sir R. Murchison was reducing to order and classifying his "Silurian" rocks § of Shropshire, which were found to repose on the

* From the German *grau*, grey, and *wacké*, a name employed by the German miners to denote some hardened grits and basaltic rocks.

† *Silurian*—a term derived from *Silures*, the ancient Britons who inhabited those parts of our Island where these strata are most distinctly developed.

‡ *Cambrian*—from the old name of Wales. In the Map, p. 474, the Silurian and Cambrian rocks are denoted by the same number (8) and colour.

§ See the classic work, "The Silurian System, founded on Geological Researches in the Counties of Salop, Hereford, Radnor, Montgomery, Caermarthen, Brecon, Pembroke, Monmouth, Gloucester, Worcester, and Stafford; with Descriptions of the Coal-fields and overlying Formations;" by Roderick Impey Murchison, F. R. S., &c., 4to, with a Map and numerous Illustrations. London, 1839. The publication of this splendid work formed an era in British geology; it is a noble monument of pa-

unfossiliferous greywacke of the Longmynd, Prof. Sedgwick was elucidating the contorted, dislocated, and slaty rock-masses of North Wales,* which he termed "Cambrian," and which were then believed to be older than any of the "Silurian" strata. The North Welsh fossils, however, were not described; nor were the exact relations of the strata of the two districts made out. Subsequently, on the one hand, it was determined, chiefly by the labours of the Geological Survey, that the fossiliferous strata of Cambria, or North and South Wales, are replications, expansions, and curvatures of the Shropshire or Silurian strata (the Cambrian equivalents being, however, for the most part, in a much more crystalline condition, and much more intersected and intercalated with igneous rocks); the fossiliferous schists both of Cambria and Siluria equally reposing on unfossiliferous greywacke—that of the Longmynd on the east, and that of Anglesea, Harlech, and St. David's, on the west. To these latter or "Bottom Rocks" the Geological Surveyors thought fit to limit the term "Cambrian;" applying the names "Lower and Upper Silurian" to the great overlying fossiliferous groups. This nomenclature became generally adopted in Europe and America, as the equivalent formations were detected and classified. At a later period Prof. Sedgwick and Prof. M'Coy, having diligently worked out the fossils of North Wales, and reëxamined much of the ground, endeavoured to define the exact limit of the lower and upper portions of the series, retaining for the former Prof. Sedgwick's early term "Cambrian," and applying that of "Silurian" to the upper group only. The Geological Surveyors also, about the same time, carefully directed their attention to the same points of research, corroborating and extending the known facts, but without essentially altering the received nomenclature.

In 1854, Sir R. Murchison published a comprehensive and popular review of the Palæozoic Rocks and Fossils, in his valuable and widely

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tient, laborious, and successful scientific research, pursued through a long series of years, regardless of toil, time, or expense. The results of the labours of its highly gifted author were alike novel and important: rocks, which, under the names of transition and greywacke, were previously considered without the pale of scientific arrangement, were for the first time reduced to a regular system, and their zoological characters as well defined as those which mark the newer secondary formations. This is truly a national work: the description of the British coal-fields is as important in an economical as in a scientific point of view.

* See the several valuable Memoirs by Prof. Sedgwick, in the publications of the Geological Society, on the Palæozoic Rocks of Wales and the North of England.